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WATER POLLUTION INVESTIGATION: DETROIT AND ST. CLAIR RIVERS

Environmental Control Technology Corporation

Prepared for:

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December 1974

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WATER POLLUTION INVESTIGATION: DETROIT AND ST. CLAIR RIVERS

ENVIRONMENTAL CONTROL TECHNOLOGY, Inc.

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGION V ENFORCEMENT DIVISION
GREAT LAKES INITIATIVE CONTRACT PROGRAM

DECEMBER 1974

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This report presents the results of a historical review and water quality survey of the St. Clair and Detroit Rivers. It includes a three-dimensional, steady-state model for the Detroit River, which will allow for the projection of future water quality based on the results of various management schemes for the Detroit Area. The historical survey illustrates a gradual upgrading of water quality in the region over the past decade, as a result of pollution abatement programs. The water quality surveys performed have provided heretofore lacking or dated information with regards to the biological communities and sediment chemistry.

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WATER POLLUTION INVESTIGATION: DETROIT AND ST. CLAIR RIVERS

by

ENVIRONMENTAL CONTROL TECHNOLOGY CORPORATION
Ann Arbor, Michigan

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In fulfillment of

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for the

U.S. ENVIRONMENTAL PROTECTION AGENCY
Region V

Great Lakes Initiative Contract Program
Report Number: EPA-905/9-74-013

EPA Project Officer: Howard Zar

December 1974

This report has been developed under auspices of the Great Lakes Initiative Contract Program. The purpose of the Program is to obtain additional data regarding the present nature and trends in water quality, aquatic life, and waste loadings in areas of the Great Lakes with the worst water pollution problems. The data thus obtained is being used to assist in the development of waste discharge permits under provisions of the Federal Water Pollution Control Act Amendments of 1972 and in meeting commitments under the Great Lakes Water Quality Agreement between the U.S. and Canada for accelerated effort to abate and control water pollution in the Great Lakes.

This report has been reviewed by the Enforcement Division, Region V, Environmental Protection Agency and approved for publication. Approval does not signify that the contents necessarily reflect the views of the Environmental Protection Agency, nor does mention of trade names or commercial products constitute endorsement or recommendation for use.

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ABSTRACT

This report presents the results of a historical review and water quality survey of the St. Clair and Detroit Rivers. It includes a three-dimensional, steady-state model for the Detroit River, which will allow for the projection of future water quality based on the results of various management schemes for the Detroit Area.

The historical survey illustrates a gradual upgrading of water quality in the region over the past decade, as a result of pollution abatement programs. The water quality surveys performed have provided heretofore lacking or dated information with regards to the biological communities and sediment chemistry.

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SECTION I

CONCLUSIONS

The connecting waters of the Great Lakes in the Detroit area are significantly affected by surrounding land uses and pollutional inputs. This fact has been observed since the earliest investigations of these waters, although the most recent data indicates a degree of recovery of water quality over the past decade.

Only minor changes in the chemical quality of the waters of the St. Clair River were observed between milepoints SR 39.0 and SR 13.7. Localized problems exist with respect to certain parameters below wastewater outfalls. A degree of enrichment in nutrients and metals was observed in the downstream sediments of this river, although the degree of enrichment was minor.

The biological communities in the St. Clair River are, in general, characteristic of unpolluted waters. Dredging operations obviously affect the benthic community, otherwise this population is characterized by clean water forms adapted to rapid current and hard substrates. The phytoplankton population is dominated by the diatoms, and does not vary significantly throughout the river.

The chemical characteristics of the Detroit River change substantially between the headwaters at Lake St. Clair and the mouth at Lake Erie. Most parameters experience increased concentrations, particularly below the influences exerted by the Rouge River and the Detroit Wastewater Treatment Plant. Similarly, enrichment of the sediments exists with respect to most parameters in this downriver area.

Established water quality standards and/or goals are presently being met, with the occassional exception of phenol and mercury in the St. Clair River, and generally with respect to total coliforms, phenol and mercury in the Detroit River. Water quality projections using the developed mathematical model for the Detroit River and present effluent limitations indicate that the goal of 2 μg/l average phenol concentration will be met by 1977.

The biological communities are similarly altered in the downstream region. The upstream area is characterized by the presence of clean-water or intermediate benthic forms, while the region between DT 18.0 and DT 12.0W is populated by pollution tolerant organisms. A limited recovery of the benthic fauna exists from DT 9.3 downstream to Lake Erie. The phytoplankton community shows considerable variation with time and distance, although there is a slight increase in number of individuals in the downstream region.

The mathematical model developed for the Detroit River was verified using several different water quality parameters. The model is verified only for the U. S. side of the river at the present time as Canadian loading information was not available at the time of writing this report. The model can be used to help evaluate the expected results of alternative management plans for the river system.

SECTION II
RECOMMENDATIONS

This program was designed to assess the present water quality of the connecting waters of the Great Lakes in the Detroit area, and to obtain the information necessary to fill existing data gaps and to allow for projections of future water quality. Due to necessary limitations in the scope of this project, many of the factors initiated to accomplish the program objectives should be continued to provide a more long-term data base and the means to make more accurate projections of water quality. The tools developed during the performance of this project should facilitate the accomplishment of these objectives.

The comprehensive monitoring programs presently being carried out by the state and provincial agencies should suffice in documenting any changes in water quality. A primary objective in this regard, however, should be to refine the data storage and retrieval systems so that all data collected on the subject water can be evaluated. Continued monitoring of the sediment phase should be undertaken to assess more fully the importance of this phase as a source and/or sink for pollutants in the aqueous phase.

Additional work is required in the development of analytical techniques to allow for broadening the scope of the monitoring program. Two notable areas of needed study are the sediment exchange phenomenon and the determination of pesticides in the sediment material. Techniques developed with regard to these two areas will allow for more accurate determinations of future water quality by means of the developed model.

The biological monitoring initiated as a portion of this project should be continued on a more routine basis, as well as being broadened in scope. A broader scope of benthic macroinvertebrate samples should be undertaken in order to define the response of individual communities to specific pollutional inputs. Samples should be analyzed taxonomically and similarity and diversity calculations performed on the obtained data. The microhabitat requirements for each group of organisms should also be recorded so that a total ecological picture of the benthos communities in all areas samples can be obtained.

Although the analysis of phytoplankton as performed in this study can serve to indicate general trends of distribution, it fails to indicate the potential of these waters for the ultimate development of nuisance algae. It is recommended that algal assay studies be undertaken to determine the relative level of significant nutrient enrichment at various locations throughout the system. It is also recommended that more extensive evaluation of photo-pigment concentrations be performed on a continuing basis, which would allow for an evaluation of any shift in phytoplankton species dominants.

Two areas of recommended study which were not within the scope of this project are biomagnification of pollutants and study of other segments of the microbiological communities. Biomagnification potential should be determined by analyzing the body tissues of various biological communities for the presence of heavy metals and pesticides. Those communities deserving of study include the fish and benthos. Because bacteria and fungi are the primary agents in the turnover of metabolizable materials and in the concentration and precipitation of certain minerals, the examination of microbial production and decomposition at various stations should be initiated.

The mathematical model developed for the Detroit River should be continually updated to reflect any alterations which may occur in the river system. This can be accomplished by reverifying the model using new loading information and water quality data as it becomes available. The model should also be verified for the Canadian side of the river once the necessary loading information is obtained. Additional sampling and evaluation of the river between DT 19.0 and DT 14.6W should be undertaken to more fully understand the drop in phenol and iron concentrations which occur. This may allow for the development of a mathematical representation of this "sink" for incorporation into the model.

Investigation and further verification of phosphorus concentrations, especially below the Detroit Waste Treatment Plant, should be undertaken to aid in explaining the difference between measured and projected concentrations. This is especially important if the model is to be interfaced with the Hydroscience Model developed for Lake Erie.

Throughout the modeling program the most critical areas of the river appeared to be between DT 19.0 and DT 14.6W, and along the U. S. and Canadian shoreline to DT 3.9. Additional studies in these areas should include information on heavy metals and other water quality parameters which may be incorporated into the modeling program. In this way, the full predictive capabilities of the model can be developed and made available to those agencies responsible for water quality management in this region.

Finally, it would be desirable to continue the mathematical modeling initiated during this project. An obvious extention of this work would be the development of a model for the St. Clair River similar to the one developed for the Detroit River. The second recommended modeling effort is the development of a dynamic model for Lake St. Clair. The third potential area for continued work in this regard would be the development of non-steady state models for the two river systems, or portions thereof.. This total effort, when coupled with an expanded, on-going monitoring program, will provide essentially all of the necessary tools for effective water quality management planning in the area.

SECTION III

INTRODUCTION

GENERAL

The water quality of the Great Lakes system has evolved as one of the most critical issues of the environmental movement, particularly during the past decade. Serving as the primary water resource of the highly industrialized and urbanized area of the upper midwestern United States and most populous region of Canada, it is logical that extensive efforts towards the protection and enhancement of the quality of these waters be made. As a result of several international agreements, most noticeably the U. S. Federal Water Pollution Control Act (FWPCA) Amendments of 1972 and the U. S.-Canada Water Quality Agreement of 1972, which have been promulgated, the Great Lakes area has been experiencing, and will continue to experience, an infusion of pollution control measures, as well as studies into the existing quality of these waters and additional measures which can be taken to protect this vital natural resource for future generations.

The most critical of the Great Lakes from a water quality aspect is undoubtedly Lake Erie. This critical nature evolves from the fact that this water body is most susceptible to manifestations of water pollution of all the Great Lakes, due primarily to its physical characteristics, as well as the fact that it serves as the primary water resource for the densely populated Detroit-Toledo-Cleveland-Buffalo area of the United States, and the developing area of southern Ontario.

The greatest affect on the overall water quality of Lake Erie has been determined to be the Detroit area, served by the connecting waters of the St. Clair River, Lake St. Clair, and the Detroit River. Approximately 93 percent of the total inflow to Lake Erie emanates from the Detroit River, consequently the following reported investigation on the existing and projected quality of these waters will serve to indicate to a considerable degree the corresponding conditions which can be anticipated in Lake Erie.

LOCATION

The water bodies of concern in this investigation serve as the connecting waters from

Lake Huron to Lake Erie. A map of this area is presented in Figure 1. Water from Lake Huron enters the St. Clair River in the Port Huron-Sarnia area, and travels for approximately 64 km (39 miles) before entering Lake St. Clair. With the exception of the Port Huron-Sarnia area at the river's headwaters, the shoreline is much less developed than the downstream Detroit River, and subsequently this body of water experiences less pollutional inputs and consequently less serious water quality degradation than the waters further downstream.

Lake St. Clair is a relatively small body of water in the Great Lakes chain, with a surface area of 1,110 square km (430 square miles) and natural volume of 3.4 cubic km (4,500 million cubic yards). Several small tributaries enter into the lake, however 98 percent of the total water input is derived from the St. Clair River. The area around the lake is not highly developed, with the exception of the southern portions of the western shore where the northeastern suburbs of Detroit are located. Water quality affects from these suburbs are minimal however, since the wastewater from this area is transported to the Detroit facility for treatment and discharge. Localized effects on the water quality do occur, however, due to the inflow of the Clinton River and combined sewer overflows.

The outflow of Lake St. Clair (mean discharge of 5,400 m^3/sec or 190,000 cfs) flows into the Detroit River and thence to Lake Erie after traversing approximately 51 km (32 miles). It is this portion of the connecting waters where the most significant pollution and degradation of water quality occurs.

The lower Detroit River (below the confluence with the Rouge River) is the most critical portion due to the discharge of municipal and industrial wastes from this point downstream.

OBJECTIVES

The primary objectives of the study reported herein is the delineation of the existing water quality and the prediction of the degree of enhancement of water quality in this region with the inauguration of "best practicable" and "best available" treatment of wastewaters. In order to accomplish this prime objective, three basic program elements were pursued.

The first task element was a thorough review of the literature with respect to previous studies performed in the water bodies of concern. An additional apsect of this task was to access the available data sources (state and provincial water quality monitoring agencies

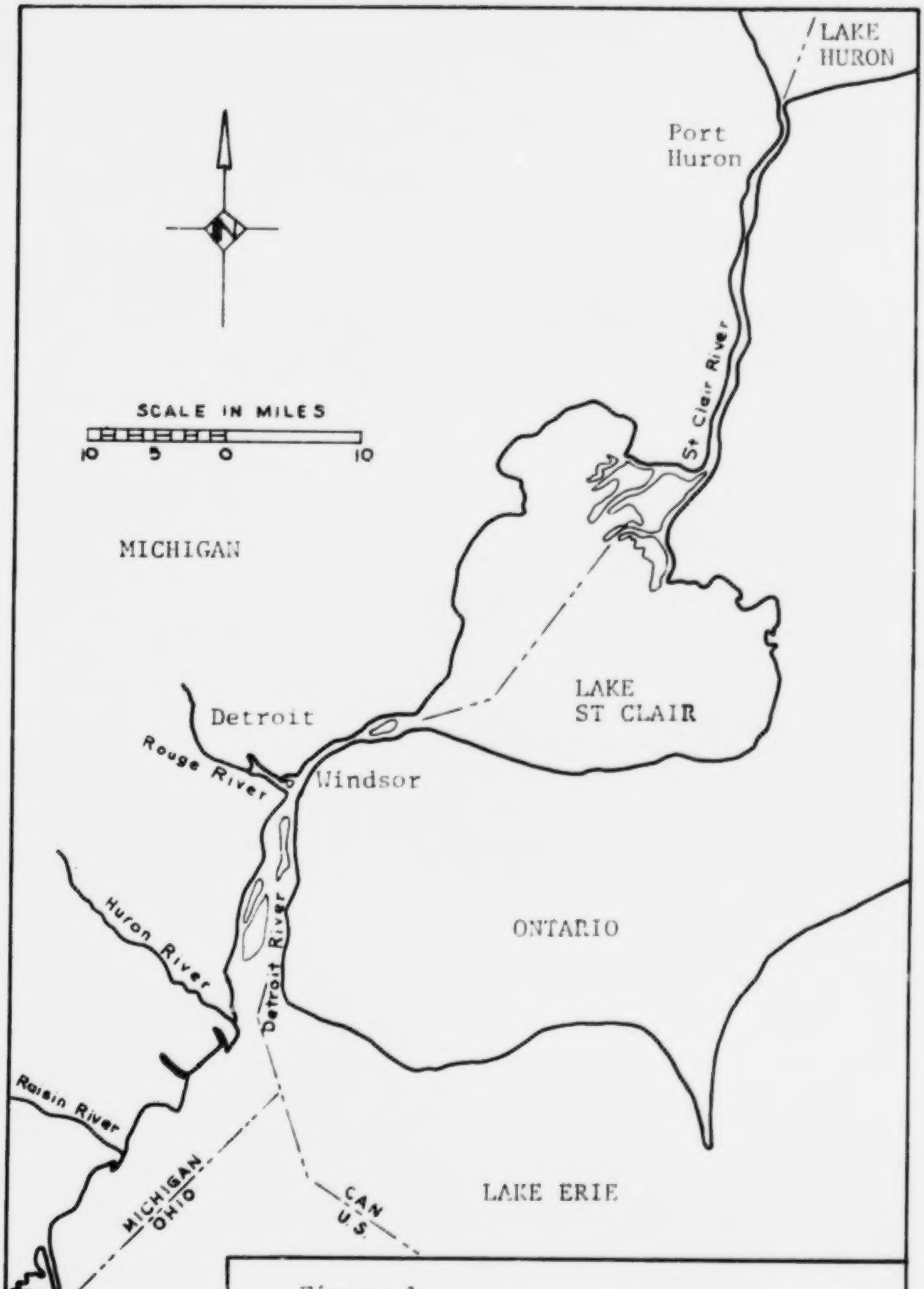

LAKE HURON
Port Huron
St Clair River
SCALE IN MILES
10 5 0 10
MICHIGAN
LAKE ST CLAIR
Detroit
Rouge River
Windsor
Huron River
Detroit River
ONTARIO
Raisin River
MICHIGAN
OHIO
CAN
U.S.
LAKE ERIE
Toledo

Figure 1
WATER QUALITY SURVEY AREA

and the STORET system) in order to determine the scope of information available.

Based on the evaluation of the existing data base, a field survey program was developed that would serve to remedy certain deficiences in presently available information, and to provide some degree of verification of the previously obtained data. Task two was then the performance of three separate water quality surveys to provide the desired additional information.

The third task element was the development and verification of a steady-state, three-dimensional mathematical model of the Detroit River. The model was developed to treat conservative substances and non-conservative substances which follow first order reaction kinetics. The use of such a model will allow for a better definition of waste inputs as well as assisting in the determination of the impact on water quality of higher degrees of wastewater treatment.

SECTION IV

HISTORICAL BACKGROUND

PREVIOUS COMPREHENSIVE STUDIES

The earliest recorded systematic survey of water quality in this general area was performed by the U. S. Geological Survey in 1906-1907[1]. This study determined the general water quality in Lake Erie and Lake Huron, but did not concern itself with the waters included in the present study area. The basic findings indicated high quality of water both above and below the Detroit area with respect to the chemical parameters monitored. No bacteriological testing was included in this study, thus this important parameter cannot be evaluated for this early period.

Prior to the U. S. Geological Survey study only isolated data from samples collected by various water treatment plants are available. Since the great majority of the intakes for these plants were purposely established in open- lake locations to avoid the influence of localized pollution sources, the analyses from these sites are relatively useless in establishing the general water quality existing during that period of time.

In 1913, a survey of coliform bacteria in the Detroit River, and certain other areas of the Great Lakes, was performed under the auspices of the International Joint Commission [2]. Although bacteriological technology and manner of reporting results has changed significantly since that time, this study is important in that it provides the first comprehensive evidence of the deterioration of the bacteriological quality of the water due to human activity and the change in land usage. The results of this study indicated that, due primarily to the absence of sewage treatment and the presence of numerous outfalls along the Rouge and Detroit Rivers, average coliform densities as measured by the Phelps Index increased from 5 per 100 ml to 11,592 per 100 ml between the head of the Detroit River and its mouth. These results can be crudely converted from this index to MPN values by multiplying the index values by 2.4, resulting in median MPN values of 12 and 27,800 at the head and mouth, respectively. In addition, the findings of this study indicated the significant shoreline effects, particularly below the developing industrial complex in the vicinity of the Rouge River.

Significant additional contributions to the data base for this region did not occur until the decade after World War II. Three major investigations were initiated during this period, two involving water quality investigations as they applied to raw water supplies for local units of government, and the third a general water quality investigation under the auspices of the International Joint Commission.

Detroit Water Supply Report, 1948

In 1948, a report evaluating the effect of combined sewer overflows into the Detroit River on the raw water supply for the City of Detroit was prepared by a board of consulting engineers [3]. This report provides little in the way of newly acquired data, however it does summarize certain aspects of water quality as it was observed at the municipal water intake at Water Works Park at the head of Belle Isle. Among the findings contained in this report that pertain to water quality in the Detroit River are the following:

a. Pollution of Lake St. Clair and the Detroit River has increased over the years, and this is reflected in the raw water quality.

b. The maximum MPN in any sample of the raw water at the intake during recent years was 15,000 per 100 cc. and the maximum daily average was 7,030 per 100 cc.

c. For the most part the high MPN values follow rains and are accompanied by recognizable increases in turbidity, but this is not always the case.

Wayne County Water Supply Report, 1955

A second investigation of river quality for water supply purposes during this period was performed by Hazen and Sawyer for Wayne County[4] . In addition to summarizing previoulsy obtained data, this study included detailed investigations of water quality of the lower Detroit River and the western end of Lake Erie. Since this study was concerned with the determination of water quality with respect to its usefulness as a potable supply, the main emphasis was on bacteriological quality and chloride levels as tracers of pollution and an indication of current distribution. The results of this study illustrated once again the significant shoreline effects of pollution, due to the relatively high rate of flow in the river which retards transverse mixing. This is shown in the median coliform density observed from Detroit Water Board sampling (1952-1955) and their study at Range C-1 (approximately milepoint 17.0W). The results for these four years, as well as previous IJC data, showed median coliform densities at a point approximately 1,500 feet from the west shore to range between 100 and 300 per 100 ml, while densities near the western shore ranged between 40,000 and 100,000 per 100 ml.

This same condition of relatively high quality bacteriologically in mid-river water and low quality (median coliform densities greater than 10,000 per 100 ml) in the water near shore was observed from the confluence of the Rouge River to the head of Grosse Ile. At this point the higher bacterial densities were observed to exist only in the Trenton Channel on the west shore of Grosse Ile, with the water in the Fighting Island Channel to the east of Grosse Ile exhibiting much lower median coliform densities. Based on the coliform data obtained in this study the following observations were made.

a. A relatively small effect of upstream pollution and combined sewer overflows from Detroit and Windsor was found to exist at Fort Wayne (milepoint 20.6) during dry weather. At this point the shore pollution was found to be limited to a narrow band, and low coliform densities prevail to within a few hundred feet of both shores.

b. The most important sources of sewage pollution along the United States shore in the lower part of the Detroit River were determined to be the Detroit Sewage Treatment Plant effluent and the Rouge River.

c. The decrease in coliform density from the United States shore to the center of the river is rapid throughout this section of the river (milepoint 20.6 to Lake Erie).

d. Characterization of the lower Detroit River as the "sewer for Metropolitan Detroit" is not warranted. The Trenton Channel does serve this purpose, but the quality of the main flow of the river is affected to only a slight degree.

e. The water in the middle of the river does not escape all pollution, but the rate of diffusion of shore pollution toward the center of the main flow is low. The best water is generally found at or near the eastern side of the ship channel.

Additional coliform analyses were performed during periods of intense storms to show quantitatively the effects of wet weather and subsequent combined sewer overflows. A total of eight sampling points were selected in order to evaluate water quality on both sides of the shipping channel at the following ranges:

Fort Wayne (approximately milepoint 20.6)

Grassy Island (approximately milepoint 15.4)

Fighting Island South Light (approximately milepoint 12.0E)

Stony Island (approximately milepoint 8.7E)

It was observed that the median coliform density near shore at Fort Wayne during wet weather was 82 times the median coliform density during dry weather. However, 1000 feet from shore the median density during wet weather was only three times the density during dry weather. Similarly, the western station at Grassy Island showed an increase of nine times, while the eastern station showed only a two fold increase. Results at Fighting Island South Light were similar to those at Grassy Island, while the Stony Island stations showed nine fold increase at the western station and a corresponding six fold increase at the eastern station. The conclusions drawn from this phase of the study were as follows:

a. While the coliform density in the mid-river water is greater following rains than in dry weather, the relative increase is small.

b. Shore pollution does not make its way across the river in concentrated slugs. The pollution that reaches the main stream is mixed with a large volume of water and diluted many times.

c. The effect of shore pollution on mid-river water quality increases moderately with distance down the Detroit River as far as Fighting Island South Light; below this point the effect is greater.

Analysis of the chloride data obtained in this study indicated the same general pattern with respect to pollution along the western shore. Average chloride concentrations at stations across the Detroit River above the Rouge River inflow were relatively constant, varying between 6.7 and 7.8 mg/l. Starting at the Rouge River the chloride concentrations along the United States shore were high, however relatively uncontaminated water, with chloride levels between 8 and 10 mg/l, was observed within a few hundred feet offshore. An important difference was observed between the coliform and chloride distributions, however, in that a sharp increase in chloride levels was found between Fighting Island and the Fighting Island Channel. These high levels were undoubtedly due to the leaching from the waste beds located on the Island. The influences of these concentrations of chloride were observed to occur in the Amhertsburg Channel to the east of Bois Blanc Island, and to have relatively little impact on the Livingston Channel between Bois Blanc Island and Grosse Ile. This information provides further substantiation on the tendency of the pollution to "streamline" along the shore.

International Joint Commission Pollution Survey, 1951

The real foundation of systematic evaluation of water quality in this region was initiated during the time interval between these two studies. On April 1, 1946, the governments of Canada and the United States directed the International Joint Commission to inquire into and report on the pollution of the St. Clair River, Lake St. Clair, and the Detroit River. This investigation extended over the period July, 1946 to December, 1948, with the final report of the findings being submitted to the two governments in October, 1950 .

The principal findings from this study were summarized as follows:

a. These waters are seriously polluted in many places on both sides of the boundary. The most serious pollution exists in the St. Clair River below Port Huron and Sarnia, in Lake St. Clair along the west shore, in the Detroit River below Belle Isle, and in Lake Erie at the west end. There is progressive over-all degradation of the water between Lake Huron and Lake Erie.

b. There is a transfer of pollution from each side of the boundary to the other. This has been demonstrated by float studies, by analytical results, and by accidental discharges of specific substances. (It should be noted that these findings are not necessarily in contradiction of the previous studies which emphasized the tendency of pollution to remain close to the shore, with the central channel of the river remaining relatively clean. Since approximately 50 percent of the total flow passes through the central portion of the river, the relatively high volume of water will tend to dilute any pollutants entering this section to a greater extent than in the near shore areas with relatively low flow rates.)

c. There has been, and remains a potential for, injury to the health and property on both sides of the boundary.

d. Substantial progress has been made in control or elimination of pollution during the period of the investigation.

The surveys performed as a part of this investigation encompassed sampling stations ranging from the southern portion of Lake Huron (approximately four miles above the head of the St. Clair River) to western Lake Erie. The extent of this survey effort can be seen in the number of stations established, as shown in Table 1.

Table 1

Body of Water	Number of transects	Total number of stations
Lake Huron (southern end)		47
St. Clair River	12	59
Lake St. Clair and tributaries		111
Detroit River	10	197

In addition, a total of six stations were established on four tributaries to the St. Clair River and six stations on four tributaries to the Detroit River. The number of samples collected and number of analyses performed during this study are presented in Table 2.

Table 2

Area of Source	Bacteriological Examinations	Chemical Samples	Examinations Determinations
Lake Huron	94	272	544
St. Clair River	1688	3082	9431
Lake St. Clair	1979	2389	14240
Detroit River	3806	4295	23894
Lake Erie	534	746	3722
Municipalities	1337	494	3327
Industries	-	788	7436
Total	9438	12056	62594

The importance of this study does not lie solely with the breadth of the survey, however, but also in the establishment of a systematic grid of sampling locations and designations of these sampling points, to allow for the correlation of the evaluation of trends in water quality as a function of time. In addition to the above accomplishment, two highly significant results of this study were the establishment of IJC objectives for water quality, and the establishment of a technical committee to maintain continuing contact with pollution control efforts and subsequent effects with respect to water quality in the area.

The basic parameters utilized in this study for evaluating the extent of pollution were total coliform levels and phenol concentrations. The water at the southern end of Lake Huron was observed to be of good sanitary quality and relatively free of any effects of pollution. Median colifrom MPN values were generally in the range of 5 per 100 ml or less, which is essentially the same as the levels observed in 1913. Similarly, high water quality was shown by chemical analysis, with dissolved oxygen ranging between 9 and 11 ppm, average BOD values from 0.5 to 1.5 ppm, and a maximum phenol level of 4 ppb.

The high quality of the water entering the St. Clair River from lake Huron was observed to continue in the middle third of the stream for a considerable distance downstream from the headwaters at milepoint SR - 39.0. High coliform levels showed heavily polluted zones near both shores in the upper section of the river, reflecting the discharge of untreated sewage from Port Huron, Marysville, and Sarnia, and the highly polluted waters of the Black River. Median coliform levels increased from five at the head of the St. Clair River to 5,400 near the United States shore at SR - 35.4, showing the influence of the Black River which enters the river approximately one mile upstream from this point. The Canadian shore is seen to be similarly influenced with median coliform values of 930 below Sarnia (SR - 35.4) and 2,400 at Cornunna (SR - 30.1E). This bacterial pollution tended toward a more uniform distribution across the entire river at milepoint SR - 17.5, with median levels of 1700, 180, 170, 240, 430 at distances from the United States shore of 100, 1200, 1700, 2200, and 2600 feet, respectively. The water leaving the St. Clair River was observed to have a bacterial load of coliform organisms 200 times greater than the water entering the river from Lake Huron.

The intensity and distribution of pollution in Lake St. Clair were seen to be influenced by the division of flows through the St. Clair flats, the direction of winds, the lake currents, the intermittent discharge of combined sewer overflows, the effects of natural purification. Basically, the water within the lake was found to be of good bacterial quality except in localized areas. The eastern portion of the lake was found to be relatively free from pollution, with the exception of a one to two mile zone at the mouths of the Chenal Ecarte and Thames River. Higher levels of coliform organisms were observed in the northwestern portion of the lake, particularly at the outlets of the north and middle channels of the St. Clair River and the Clinton River. These sources, along with combined and storm sewer overflows from the lakeside communities, result in relatively higher levels of pollution along the western shore of the lake. Patterns of relative phenol concentrations follow the same general spatial relationship as the coliform values, which is to be expected since both parameters are influenced by the same water movement. Average phenol values were found to be generally below 10 ppb.

The analytical results for the Detroit River showed a littoral stratification similar to that observed in the St. Clair River, with pollution effects remaining near the respective shores in the upper reaches and spreading and diffusing across the entire width of the stream below Fighting Island. Median coliform levels approached 100 per 100 ml along both shores at the entrance to the Detroit River, with a value of about 10 at midstream. A significant increase in coliform levels was observed on the United States side at the head of Belle Isle as a result of combined sewer overflows emanating from Conners Creek. Median coliform levels at this range (DT - 29.2W) were 200,000 and 93,000 per 100 ml at distances offshore of 50 and 100 feet, respectively. Moving downstream, the bacterial pollution retained its shore hugging characteristics, although the zones of higher coliform levels were observed to extend farther out from shore. Upstream from Zug Island - Rouge River industrial complex (DT - 20.6), median coliform levels of 24,000 per 100 ml were observed at the United States shore, decreasing to 2,400 per 100 at a distance of 300 feet from shore. Median values near the Canadian shore at this range were 8,200 and 2,400 at offshore distances of 100 and 400 feet, respectively. The mid-river median levels at this range increased to 93 per 100 ml. Bacterial pollution from the Rouge River and the Detroit Sewage Treatment Plant have an immediate effect on the United States shoreline, resulting in a median coliform level of 93,000 at DT - 19.0 just 0.8 mile downstream from the Rouge River. Surface currents from the Rouge River - Zug Island area were observed to tend to cross the international boundary and to flow to the east of Fighting Island. This results in a relatively uniform distribution of coliform across this channel at levels between 1,500 and 3,500 per 100 ml. The channel to the west of Fighting Island was characterized by high coliform levels near the United States shore and extending about one half the distance to the Island. Median coliform levels from this point to the island shore were about 100 per 100 ml. As the flow continues downstream to Grosse Ile, the heavier pollution along the United States shore tends to enter the Trenton Channel on the west side of the Island resulting in observed median coliform levels of 10,000 per 100 ml and higher. The flow on the east side of the Island shows the pollution fairly well distributed across the channel at milepoint 9.3E, with median levels ranging from 1,100 to 9,300. At range DT - 3.9, across the mouth of the river, the bacterial pollution on the Canadian side remained constant at about 5,000 MPN, while an increase was observed on the United States side due to the highly polluted waters from the Trenton Channel, with median values reaching 43,000 per 100 ml.

Significant concentrations of phenol were observed primarily on the United States side of the river downstream from the Rouge River. Average phenol values at this transect (DT - 19.0) ranged from 11 to 39 ppb for a distance of 400 feet offshore, due to discharge of phenols from the Rouge River (average concentration of 79 ppb) and the Detroit Sewage Treatment Plant. Phenol concentrations upstream from this transect and on the Canadian side are generally 8 ppb or lower. These elevated phenol concentrations were observed to remain near the United States shore, with the primary pollution resulting from this parameter occurring in the Trenton Channel on the west side of Grosse Ile, where average concentrations of 12 to 24 ppb were determined. Significant phenol pollution was observed in Monguagan Creek, which enters the Trenton Channel immediately below the sampling transect DT - 12.0W. This tributary exhibited an average phenol concentration of 3,490 ppb. At range DT - 3.9, the phenol concentration exhibited generally the same pattern as the coliform, in that there is a diffusion across the river, with higher concentrations on the United States side due to the quantities added from the Trenton Channel. BOD and ammonia results showed low values above the mouth of the Rouge River, with somewhat elevated levels below this point.

Comparing the average coliform results between the 1913 study and the 1946-1948 study, it was observed that, while Lake Huron had remained essentially constant, the total bacterial load at the mouth of the Detroit River had increased approximately three fold. The overall increase from Lake Huron to the mouth of the Detroit River was approximately 800 times in 1913 and over 2,400 in 1946-1948.

U. S. P. H. S. Water Quality Survey, 1965

In March of 1962 a conference was held at the request of the State of Michigan to discuss the present status of pollution in the southeast Michigan area. As an outgrowth of this conference, the Detroit River-Lake Erie Project was established by the United States Public Health Service to determine the extent of pollution in the United States portion of the Detroit River and the Michigan section of Lake Erie. In addition, this project was to investigate the principal sources of pollution in this area, the contribution from these sources, the effect of pollution on various water uses, and to prepare a plan for pollution abatement in the area.

In order to provide this information, a comprehensive study was initiated in 1962, with the final report presented in April of 1965[6]. This report provides a detailed analysis of the various water usages in the area, population and manufacturing trends, municipal and industrial waste sources and their characteristics, and description of water quality.

The investigation of bacteriological quality showed that the total coliform concentration near the United States shore, from Belle Isle to the mouth of the river, were significantly affected by storm overflows, showing a five to ten fold increase during these periods. Under dry conditions, the coliform level was not found high enough to interfere with any water uses, except below the Rouge River and the Detroit Sewage Treatment Plant outfall, in the United States section of the river. During or following periods of sufficient rainfall to cause overflow of combined sewers, however, the entire river below Belle Isle was found to be polluted to the extent that it is unsafe for recreational usage. In addition to total coliform determinations, fecal coliform and fecal streptococcus analyses were performed during the course of this study. Fecal coliforms were found to comprise from 30 to 90 percent of the total coliform population, with the higher values occurring below the Rouge River during wet periods. At the mouth of the river the fecal coliform densities ranged from 30 to 65 percent of the total of 1,000 to 10,000 per 100 ml. Fecal streptococci levels were considerably lower than coliform levels, particularly during wet conditions.

One of the more critical chemical parameters investigated was the phenol concentrations in the river. IJC objectives call for average phenol concentrations not to exceed 2 μ g/l and maximum values not to exceed 5 μg/l, in order to prevent taste and oodors in water supplies[5]. These criteria were exceeded at all ranges in the Detroit River during the study period. Average phenol concentrations in the upper Detroit River ranged from 3 to 5 μg/l, while a near shore station just below the Rouge River exhibited an average concentration of 28 μg/l. High phenol levels were particularly noticeable in the tributaries of the Detroit River with maximum values of 10,980 μg/l and 290 μg/l in Monguagon Creek and the Rouge River, respectively. Average phenol concentrations in these two tributaries were 1500 and 12 μg/l, respectively. Average concentrations at the mouth of the Detroit River ranged from 4 to 9 μg/l on the United States side of the International Boundary, with from 33 to 70 percent of the samples taken within 5,500 feet of shore showing concentrations in excess of 5 μg/l.

The other chemical parameters investigated include: solids, chloride iron, biochemical oxygen demand (BOD), dissolved oxygen (DO), nitrogen compounds, phosphates, pH, ABS, alkalinity, chemical oxygen demand (COD), cyanide, hardness and certain toxic metals. Although, in general, no serious problems were encountered with respect to the concentrations of these materials, and little in the way of specific trends was delineated, there was illustrated a general degradation of quality below the Rouge River. This was particularly true with respect to chlorides, BOD, COD, and certain heavy metals.

Biological analysis was incorporated as a portion of this study, with investigations made of microscopic plants and animals and bottom dwelling organisms. The free-floating phytoplanktonic organisms were found to be relatively unchanged through the course of the river, with the population basically dependent on those plankton which enter from Lake St. Clair. The sewage fungus, Sphaerotillus , was found growing attached to submerged objects, being particularly abundant below the Rouge River and Detroit Sewage Treatment Plant outfall. Of the biological communities analyzed, the benthic organisms most clearly illustrated the effects of pollution. Bottom samples collected at the headwaters above Belle Isle contained a variety of clean-water associated species, such as caddisfly larvae. Downstream from Belle Isle, along the Michigan shore, there no longer existed the pollution-sensitive organisms, rather a preponderance of sludge worms and leeches were collected. Forms with intermediate tolerances were found along the United States shore from approximately range DT - 25.0 to the confluence of the Rouge River. At this point a band of extremely pollution tolerant organisms existed, with essentially no clean-water forms observed further downstream.

This study also included a comprehensive study of waste loadings from municipalities and industries in the general area. A summary of the waste loadings determined from this survey is presented in Table 3.

Table 3. SUMMARY OF DAILY AVERAGE WASTE LOADS IN DETROIT RIVER - UNITED STATES SIDE (1963-1964)

Source	Total waste flow (MG)	Phenols (lbs)	Cyanides (lbs)	Ammonia (lbs)	Oils (gal)	Suspended Solids (lbs)
Industrial	1090	1410	1030	8530	3350	822000
Municipal	541	1270	3	34300	16000	626000
Total	1631	2680	1033	42830	19350	1448000

The analysis of water quality and waste loadings as determined in this study showed a general improvement in water quality in the lower Detroit River when compared to the

IJC survey of 1947-1948. This was particularly true with respect to coliforms and phenol. The major reasons for this improvement appeared to be the progress made in pollution abatement by the industrial segment during the preceeding fifteen years. Reduction of 70 to 80 percent in total loadings of phenol, cyanide, and oil was achieved by industry during this period, along with a 22 percent reduction in ammonia loading and 51 percent reduction of suspended solids loading. Municipal sources were not analyzed during the previous survey, so no similar evaluation could be made for this sector.

Subsequent to this survey (1962-1963) routine monitoring of river water quality and point source discharges has been performed by the Michigan and Ontario Water Resources Commissions. The data from these surveys are forwarded to the IJC for their use as well as the Commissions'. Summary reports based on this data are periodically prepared by the IJC which evaluate the progress being made in pollution abatement. These results will be considered in the discussion of water quality trends later in this report.

EXISTING MONITORING PROGRAMS

Since the conclusion of the comprehensive study of the Detroit River performed by the U. S. Public Health Service, a continuing water quality survey program of the Detroit area interconnecting waters has been maintained by various governmental agencies. At the present time, The State of Michigan and the Province of Ontario have the prime responsibility for the monitoring of these waters. In addition, the U. S. E. P. A. provides continuing surveillance at selected stations. Although certain stations which were sampled by the Public Health Service and in the early portion of the monitoring program have been abandoned, and certain other stations have been established in recent years, the current program has continued numerous stations which have been sampled several times each year for the present decade. The information from these stations allows for the examination of trends in water quality with respect to several parameters.

The river transects currently being monitored (1973) season, each of which generally has a number of stations located across the river, are listed in Table 4.

In addition to the continuing monitoring program, additional studies are performed periodically, such as industrial waste surveys, and the extensive study of Lake St. Clair performed by the Michigan Water Resources Commission in the summer of 1973.

Table 4. CURRENT MONITORING TRANSECTS

Transect	Stations per transect United States Agencies	 Canadian Agencies
St. Clair River		
SR 39.0	2	5
SR 35.0		2
SR 34.4		2
SR 33.9		3
SR 33.1	6	6
SR 30.7	7	6
SR 26.7	6	6
SR 17.5	6	6
SR 13.7	6	6
SR 10.0 S	3	
SR 10.0 N	3	
SR 7.6 N	3	
SR 4.1 N	3	
Detroit River		
DT 30.8 W	7	7
DT 30.7 E	3	4
DT 25.7		2
DT 20.6	5	5
DT 20.2		4
DT 19.0	6	9
DT 17.0 E	3	3
DT 14.6 W	7	
DT 13.12		3
DT 12.0 W	3	
DT 9.3 E	8	8
DT 8.7 W	3	
DT 6.7 E		2
DT 6.2 E		1
DT 3.9	11	12

WATER QUALITY TRENDS

Methodology

The water quality data obtained by governmental agencies within the United States is on file in the STORET system maintained by the U. S. Environmental Protection Agency. A similar system, maintained by the Ontario Ministry of the Environment, contains the data obtained by the Canadian agencies. Due to time restrictions, only the STORET system was accessed in order to obtain the data which would allow for the delineation of water quality trends for the two rivers of concern in this project. A total of six transects in each of the rivers were used in the analysis, since these milepoints were the ones containing sufficient long-term data to allow for meaningful interpretation.

In general, the data was analyzed by using the annual averages for various parameters at the selected stations. In order to reduce the affect of any anomalies in the data, three year moving averages were computed, thereby considering larger sample sizes (15-20 observations). Based on the preliminary analysis of such data transformation, it appeared that a random grouping of yearly averages would best portray the average water quality conditions for specific periods of time. Based on the data available and trends observed from annual averages, the St. Clair River was grouped into the years 1946-1947, 1964-1969, and 1970-1973, while the Detroit River was evaluated by comparing 1962-1963 data with that from 1971-1973. Any statistical error which might have been induced by comparing averages for various time durations was not investigated. It must also be stressed that the concentration values observed do not take into account any variation in total river discharge. Indications are that the discharge has increased approximately 10 percent over the last decade (see Appendix D-3).

While the above approach provided a degree of qualitative indication of water quality trends over the past decade, a more rigorous analysis was made by a statistical comparison of the mean annual values at selected stations for the years 1968 and 1973.

Statistical evaluation of yearly means of selected chemical and biological parameters was accomplished utilizing a t-test of the differences between two means. The null hypothesis is that if the two samples come from the same population, they must have the same parametric mean ($\mu_1 = \mu_2$). This test assumes equal variances in the two samples. An alternative test considers two samples from different populations being heteroscedastic (i.e. variances not equal).

Testing the homogeniety of variances of two sample sets was done utilizing the F test, which calcualtes the ratio of the greater variance over the lesser one. When the homogeniety of variance assumption was not tenable, the differences between the means were tested using the t' test. The confidence limits for all tests were 95 percent.

The formulae used in evaluating the data are summarized as follows:

A. Testing the homogeniety of variances.

$H_O: \sigma_1^2 = \sigma_2^2$

$H_1: \sigma_1^2 \neq \sigma_2^2$

$F_s < F_{.05}(V_1, V_2)$ accept null hypothesis

$F_s > F_{.05}(V_1, V_2)$ accept alternative hypothesis

B. t-test means of two samples

null hypothesis accepted ($H_O: \sigma_1^2 = \sigma_2^2$)

$H_O: \mu_1 = \mu_2$

$H_1: \mu_1 \neq \mu_2$

$t_s < t_{.05}(V_1, V_2)$ accept null hypothesis

$t_s > t_{.05}(V_1, V_2)$ accept alternative hypothesis

C. t' test means of two samples

alternative hypothesis accepted ($H_1: \sigma_1^2 \neq \sigma_2^2$)

$H_O : \mu_1 = \mu_2$

$H_1 : \mu_1 \neq \mu_2$

$t'_s < t'_{.05}$ accept null hypothesis

$t'_s > t'_{.05}$ accept alternative hypothesis

Finally, the data output from the STORET system was examined to check the compliance of water quality with established standards and goals. The water quality standards established by the State of Michigan for the St. Clair and Detroit Rivers are summarized in Table 5 [7].

Table 5. WATER QUALITY STANDARDS FOR THE ST. CLAIR AND DETROIT RIVERS

Chlorides	50 mg/l monthly average
Dissolved Oxygen	6 mg/l
Filtrable Iron	0.3 mg/l
pH	6.7 to 8.5
Fecal Coliform	200 per 100 ml
Toxic Substances	limited to concentrations established in Federal Standards

For the purposes of evaluating the concentration of toxic heavy metals, the levels recommended in the Water Quality Criteria-1972, published by EPA were used[8]. Pertinent recommended criteria from this report are shown in Table 6.

Table 6. ALLOWABLE HEAVY METAL CONCENTRATIONS

Cadmium	30 micrograms per liter
Chromium	50 micrograms per liter
Copper	0.1 x 96 hour-LC_{50} *
Lead	30 micrograms per liter
Mercury	0.05 microgram per liter average 0.2 microgram per liter maximum
Nickel	0.02 x 96 hour-LC_{50} *
Zinc	0.005 x 96 hour-LC_{50} *

*LC_{50} values not established for this water

St. Clair River

Prior to 1970, comprehensive data collection on the St. Clair River was limited to the survey undertaken in 1946-1948 under the auspices of the International Joint Commission, as reported in the historical review. In the mid-fifties, and again in the mid-sixties, a limited amount of water quality data was obtained, particularly with respect to the phenol concentrations. Insufficient data is available for these periods to perform a rigorous trend analysis, however, certain general observations can be made for this period. Routine, systematic monitoring of the St. Clair River at a number of new, as well as at several previously established stations, has existed since 1970. The continued monitoring of these stations will provide greater insight into overall water quality of the river, however the four recently established stations do not provide sufficient data to allow for the establishment of any trend. Consequently, only the six on-going stations will be considered in this analysis. Furthermore, only chloride and phenol concentrations have received enough emphasis at these stations to allow for a systematic analysis.

Results

Chlorides - The chloride concentrations at the head of the river (SR 39.0) have remained relatively constant, with discrete samples ranging from 3 to 12 mg/l, and annual average values ranging from 4.7 to 6.7 mg/l. A variation of the average chloride concentration can be seen, however, at station SR 26.7 (Figure 2). The station located 100 feet from the United States shore showed a slight improvement from 1946 to 1969 (8.1 mg/l to 7.6 mg/l), however, the most recent data shows the average values 1,900 feet from the United States shore going from 8.2 mg/l (1946- 1947) to 13.3 mg/l during the late 1960's and back down to 7.4 during 1970-1973. These changes are also reflected in mid-river water quality, where the average chloride concentration has risen from 5 mg/l in 1946-1947 to 6.6 mg/l and 7.2 mg/l for 1964-1969 and 1970-1973, respectively.

The next station downstream for which continuing data is available is located at SR 17.5 (Figure 3). The average chloride levels for three different sampling periods can be seen to remain relatively constant in the western portion of the river, except for the station located 100 feet from shore, where the level has increased from approximately 8.5 mg/l in both 1941-47 and 1964-65, to 10.6 during the period 1970-73. Results obtained near the Canadian shore follow closely the conditions observed at SR 26.7, where a large increase was observed in 1964-65, with a reduction in chloride levels found since 1970. The same conditions observed at SR 17.5, were found at station 13.7 (Figure 4).

Figure 2. Trends in chloride concentration St. Clair River SR 26.7

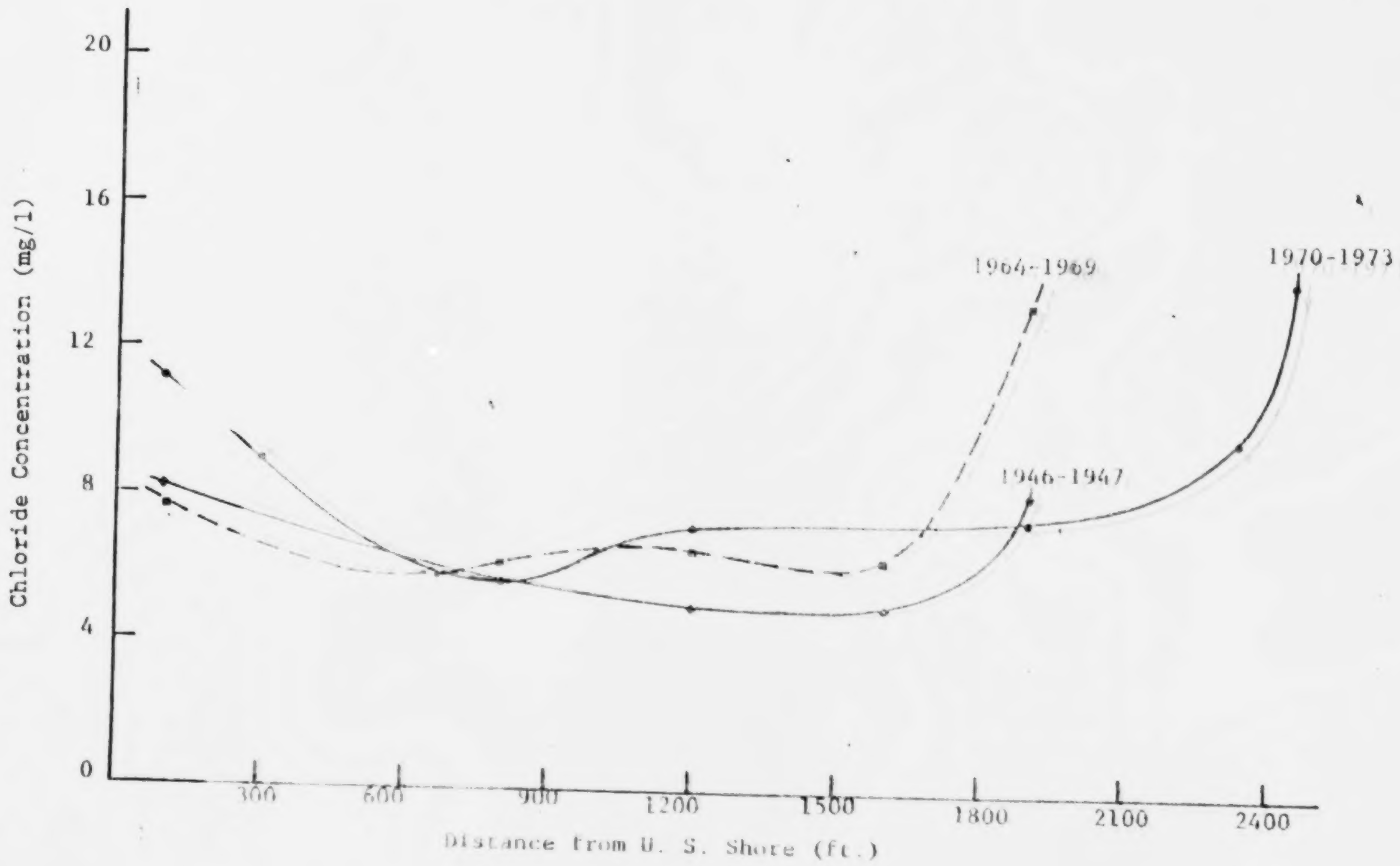


Figure 3. . Trends in chloride concentration St. Clair River SR 17.5

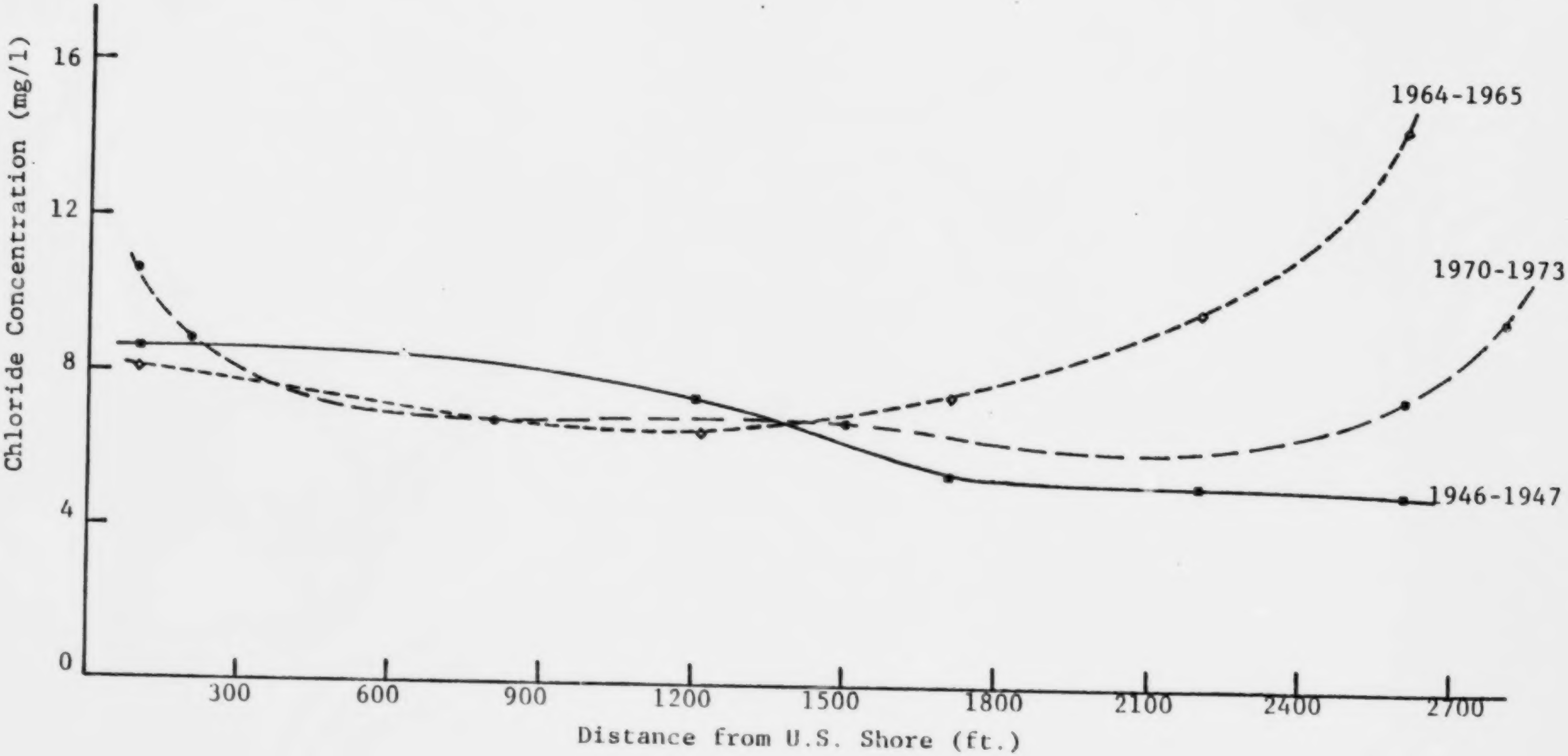
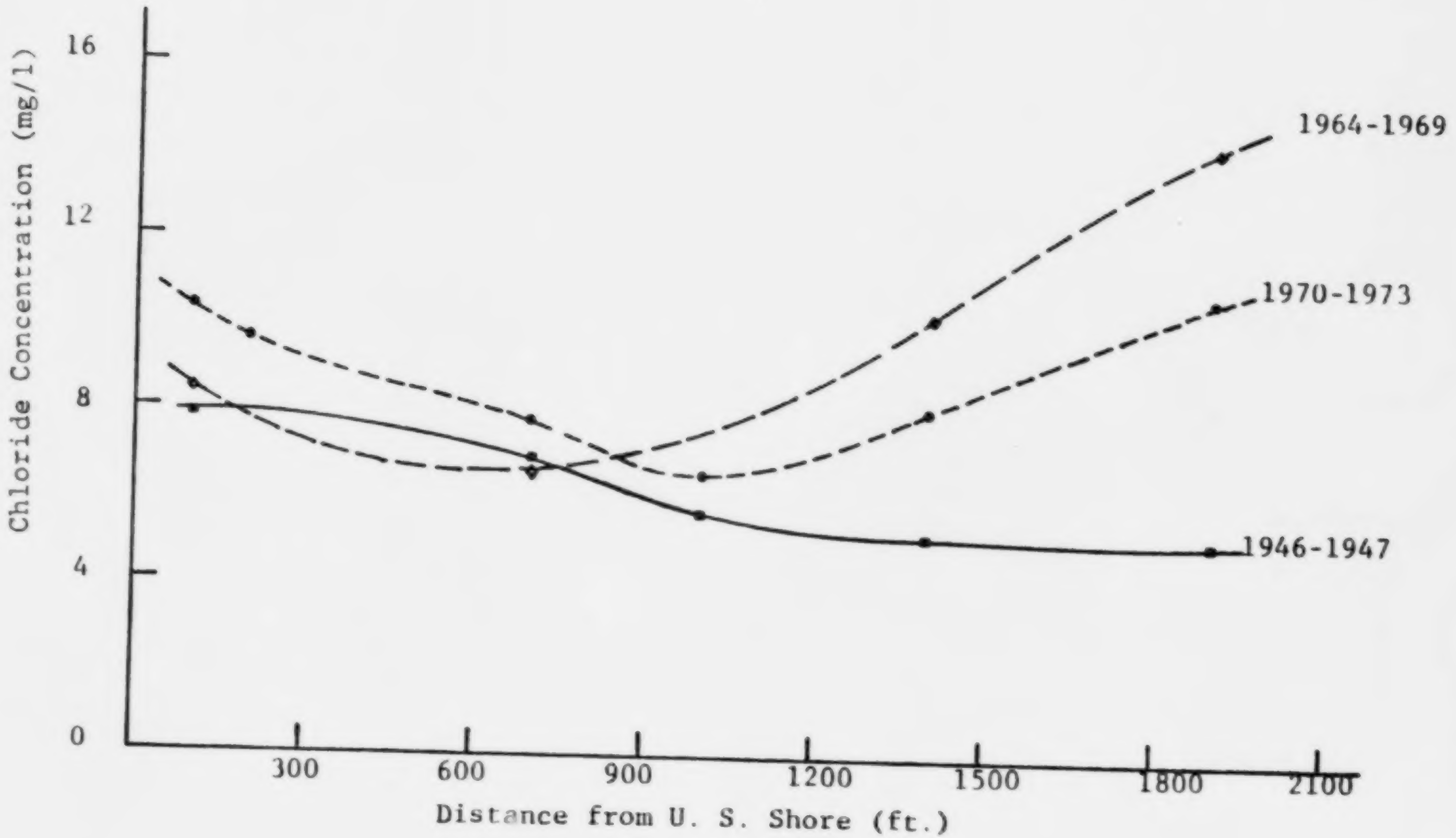


Figure 4. Trends in chloride concentration St. Clair River SR 13.7



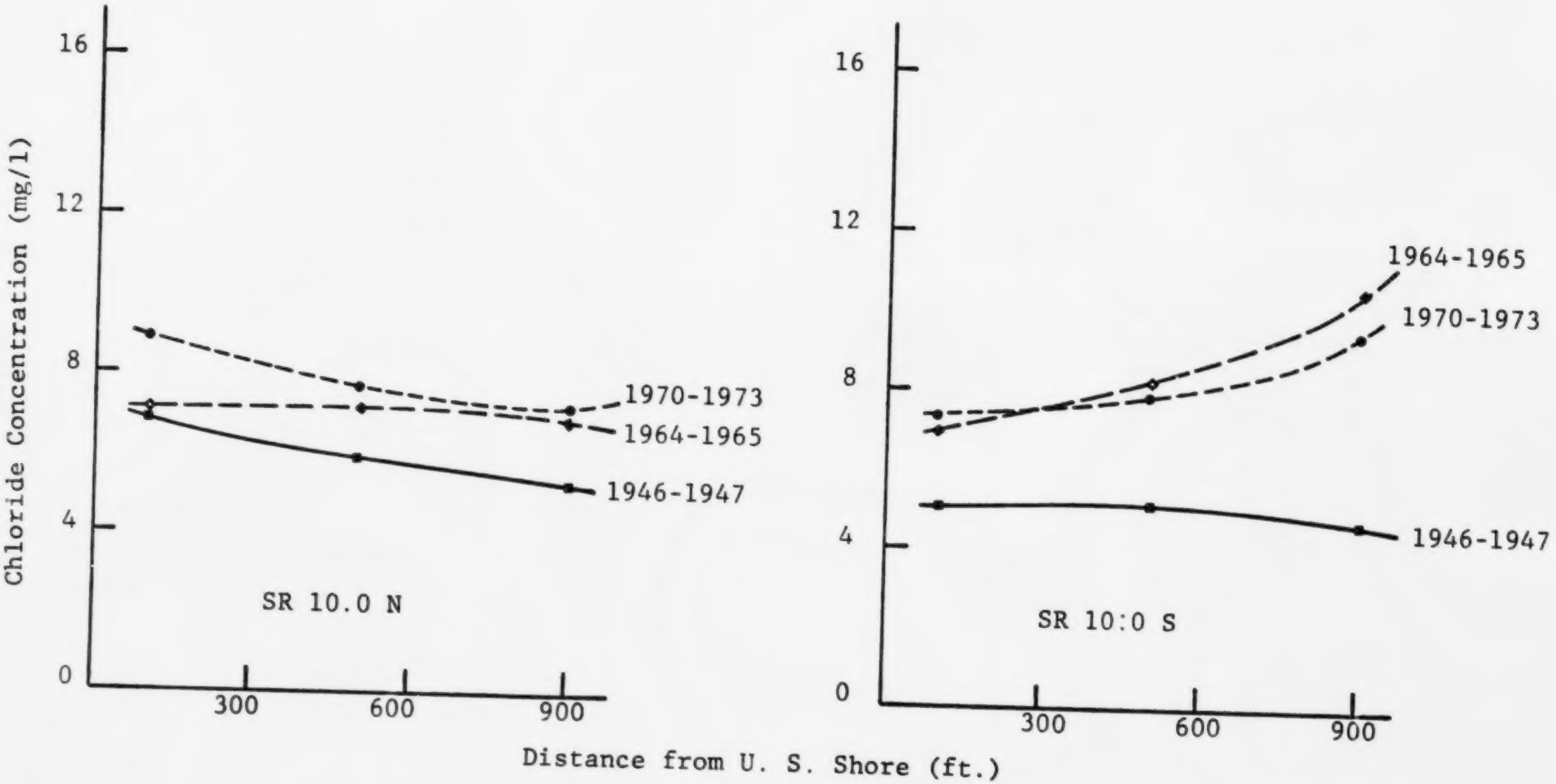
The final station for which sufficient monitoring has been performed to allow an analysis of water quality trends is located at SR 10.0, which is located below the point where the river splits into a north and south channel around Harsons Island. Results obtained in the south channel follow closely the results obtained at SR 17.5 and SR 13.7, with a relatively large increase in chlorides between 1946-47 and 1964-65, with a small decrease observed since 1970. The north channel can be seen (Figure 5) to have experienced a continual increase in chloride levels, although the magnitude of this increase has been relatively small (6.8 mg/l to 8.9 mg/l).

Phenol - Phenol levels were found to be relatively high at most stations monitored during the 1946-47 survey, with all stations having at least one sample which exceeded the IJC objectives of a maximum 5 μg/l, and many stations exhibiting maximum concentrations of 100 to 400 μg/l. Sampling programs during the 1950's showed phenols to remain a problem, however, a marked decrease in phenol concentrations was observed. Only one sample exhibited a concentration in excess of 50 μg/l, however, a total of 33 stations had maximum concentrations in excess of the 5 μg/l objective. During the 1960's, the number of stations where the maximum value was exceeded was reduced to 19, and the maximum concentration observed was 30 μg/l.

By the 1970's, only two stations continued to exhibit a significant concentration of phenol: SR 30.7 and SR 33.1. In both cases, the high maximum values were observed only at one station located nearest to the Canadian shore, and to have little effect on the offshore water quality. For example, the maximum concentrations observed during this period occurred in 1973 at SR 33.1, 2,030 feet from the United States shore, with a range of 1 to 21 μg/l for six samples, and an average of 5.67 μg/l. During this same period, the station located 100 feet further out from shore ranged from 1 to 2 μg/l, with an average of 1.67. The effect of this concentration was manifest in the next downstream station (SR 30.7 - 3,700 feet) where the phenol concentration ranged from 1 to 7 μg/l, with an average of 3.33. Here the effect could be observed further from shore (SR 30.7 - 3,550 feet) where the values ranged from 1 to 4 with an average of 2.33. Downriver from this point, no values above 4 μg/l were observed.

It is thus obvious that considerable progress has been made in preventing phenol pollution in the river. With the possible exception of the industrial area south of Sarnia, the phenol pollution sources have been reduced to the level where IJC objectives for the river are being met.

Figure 5. Trends in chloride concentration St. Clair River - SR 10.0 N and SR 10.0 S



Other parameters - Other parameters of interest in establishing water quality have received systematic, continuing investigation only since the late 1960's or early 1970's. A small amount of information on coliform and ammonia concentrations was obtained during the 1946-47 survey, however, the methods of analyses used for these parameters has changed such that little insight is gained in comparing these earlier values with those obtained during the more recent surveys.

Total coliform data was obtained in 1946-47 by the MPN method, whereas the membrane filter method has been utilized in more recent surveys. Qualitative indications are that a decrease in this parameter has occurred over the last two decades. Mean total coliform levels are low at all stations (less than 1,000 per 100 ml) with maximum values within the IJC goal of 1,000 per 100 ml. Fecal coliforms, although monitored only for the last decade, show the same trend, generally accounting for approximately 10 to 50 percent of the total coliform population.

Ammonia nitrogen was determined in 1946-47, and is included in current monitoring programs. In general, ammonia was not detected during the earlier survey, however the increased sensitivity of current analytical techniques with respect to ammonia precludes attributing the presently detected levels to an actual increase in concentration. Nitrate nitrogen and phosphorus were monitored periodically during the late 1960's, and have been routinely monitored since 1970 with no appreciable trend being observed during this period.

Little variation in suspended or dissolved solids has been observed, with the exception that the most recent sampling season saw a significant increase in suspended solids at the upstream stations. This is too short a time span to state affirmatively that a trend is developing, however it does warrant paying particular attention to this parameter during subsequent sampling seasons.

Statistical evaluation of the data from the St. Clair River was made for stations located at milepoints SR 39.0 and SR 13.7. The results of comparing 1968 and 1973 mean values is presented in Table 7. The three parameters for which significant differences of annual means could be established were chlorides, nitrates, and total coliforms. As is shown in Table 7, the chloride concentration at stations near the Canadian shore at SR 13.7 have decreased significantly over the past five years. The nitrate concentration has exhibited a significant decrease at milepoints SR 39.0 and SR 13.7 at most stations monitored. The total coliform level, however, was observed to have increased significantly at the head end of the river. Phenol and iron concentrations were also tested, however no significant variation could be established between these two periods.

Table 7. STATISTICAL EVALUATION OF MEANS - ST. CLAIR RIVER 1968 versus 1973

River Mile	Distance from shore (ft.)	Chlorides	Nitrates	Total Coliforms
39.0	100			
	4 foot depth	-	1968>1973	1968<1973
	30 foot depth	-	1968>1973	-
	1500	-	-	1968<1973
13.7	100	-	1968>1973	-
	700	-	-	-
	1000	-	1968>1973	-
	1400	1968>1973	-	-
	1900	1968>1973	1968>1973	-

Generally speaking, the most recent surveillance data shows the water quality of the St. Clair River to be in compliance with established standards and goals.

Detroit River

As discussed in the previous sections, the past two decades have seen increased activity in the assessment and control of the water quality of the area. Prior to 1962, only limited studies were undertaken to assess the water quality conditions, thus making a detailed trend analysis for this time period extremely difficult. Some general conclusions can be made, however, by considering the 1913, 1948, and 1962 studies performed under the auspices of the International Joint Commision. The data from these studies has been discussed in the previous sections and the following conclusions made. During the time period of 1913 to 1948 the general water quality of the Detroit River continued to deteriorate as measured by coliform bacteria and phenols. After the 1948 study, substantial progress in pollution abatement was realized, and subsequently the general water quality improved between 1948 and 1962.

In 1962 a comprehensive study the United States Public Health Service was initiated in order to further assess the existing water quality. A number of stations established during this study have been continually monitored up to the present time. Since 1966 most of these stations have been maintained by the Michigan and Ontario Water Resources Commissions. The data obtained during the course of the monitoring program provides a data base for evaluating the trends in the water quality of the river over the past ten years. The following discussion analyzes the changes in water quality over the past decade as measured by several water quality parameters. These parameters include total coliform, phenols, chlorides, ammonia nitrogen, nitrate nitrogen, total phosphorus, total iron, cyanide, and total dissolved solids.

The STORET system maintained by EPA contains the water quality data from the United States Public Health Service and Michigan Water Resources Commission surveys. This retrieval system was used to access the data and to provide annual statistical summaries for all of the stations which have been monitored. A similar system is maintained by the Province of Ontario, however this system could not be accessed in time to include the data from this source.

A total of 23 stations located at six different milepoints along the Detroit River were used in the analysis. These stations span the entire length of the river from the head of the river at Lake St. Clair to the mouth of the river at Lake Erie. The stations were chosen based on their location in the river and on the amount of data which was available. Each of these stations was sampled five or six times during each year, this sampling occurring approximately once a month from late April to early October.

Results -

Chlorides - The chloride concentrations have remained relatively constant at the head of the river varying from 8-10 mg/l. There appears to have been a significant decrease, however, in the concentrations in the lower portions of the river (milepoint 14.6 and below). The largest decreases wery found at stations in the Trenton Channel at milepoint 8.7W. Graphical comparisons of the 1962-63 versus 1971-73 chloride levels are shown in Figures 6-10. These decreases have resulted in the water quality now complying with the chloride standard.

Phenol - Phenol concentrations have also generally decreased during the last ten years. Again the most significant reduction has occurred in the Trenton Channel at milepoing 8.7W. Only two stations exhibited an increase in phenol concentration; both of these being located at milepoint 14.6. Even though a general reduction has occurred, the near-shore stations in the lower river, and all of the stations in the Trenton Channel, continued to exceed IJC goals of 2 μg/l average and 5.0 μg/l maximum. Comparisons of the data for various years is given in Table 8 and Figure 11.

Total coliform - It was difficult to assess a trend with regards to total coliform. Primary sources of coliform loadings are the combined sewer overflows located along the river. Due to the intermittent nature of these discharges, the sampling conditions as a function of time since the last rainstorm, size of the storm, etc., are very critical when considering the coliform concentrations. This is illustrated by the fact that for any given year large variations occur between the maximum and minimum levels recorded. At several stations these variations span several orders of magnitude (e.g. 100-10,000/100 ml). Because of this large fluctuation, examining the data on a year to year basis provided little help in defining a trend. At any given milepoint, several stations would show an increase, while others showed decreased concentrations. Analyzing the data using three year moving averages, however, tended to smooth out the yearly fluctuations and indicated that, on the average, some changes have occurred. Figures 12 through 18 present graphical comparisons of the averages for the years 1962-63, 1967-69, and 1970-72. In all cases,

Figure 6. Trends in chloride concentrations Detroit River - DT 20.6

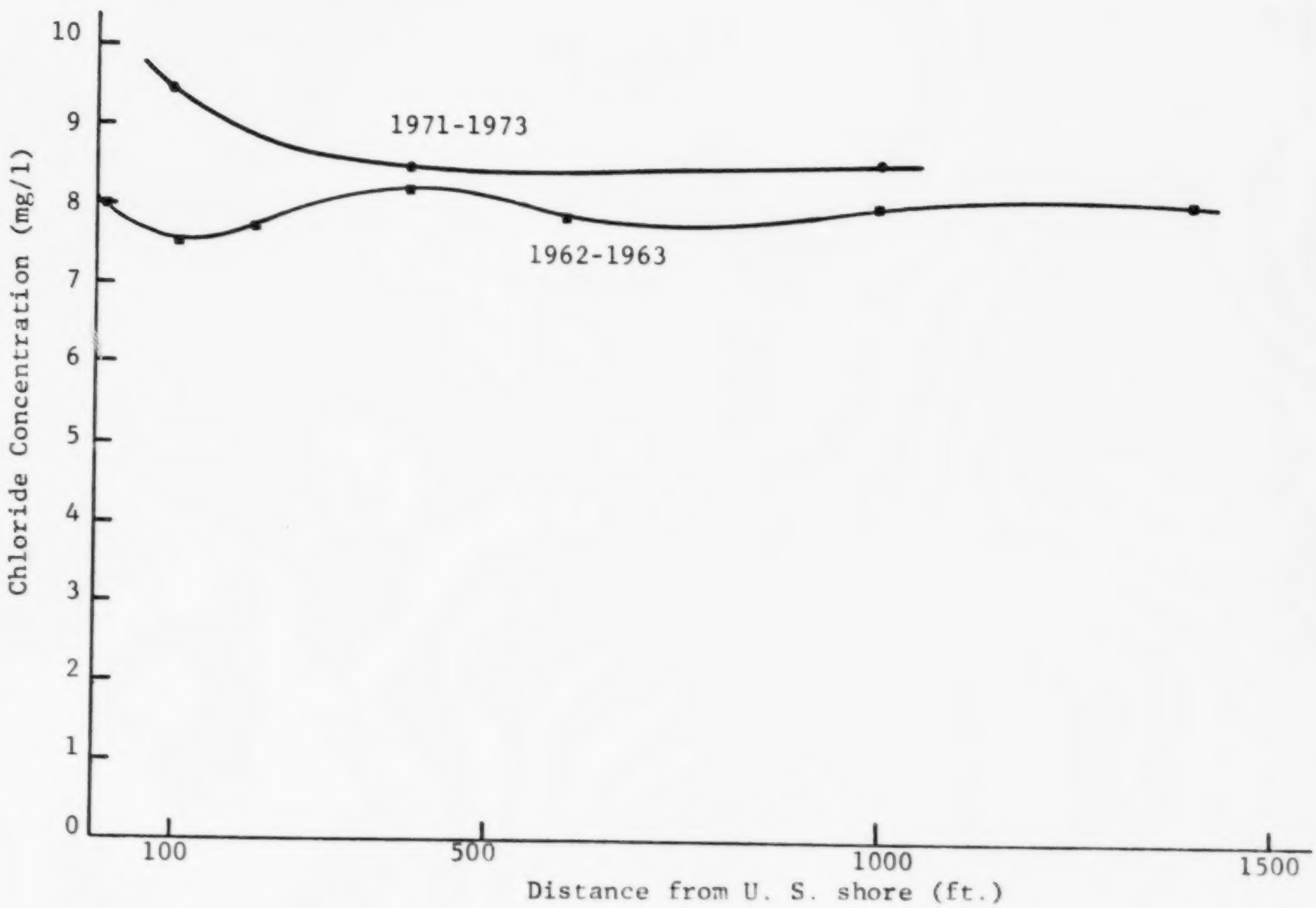


Figure 7. Trends in Chloride Concentration - Detroit River DT 14.6

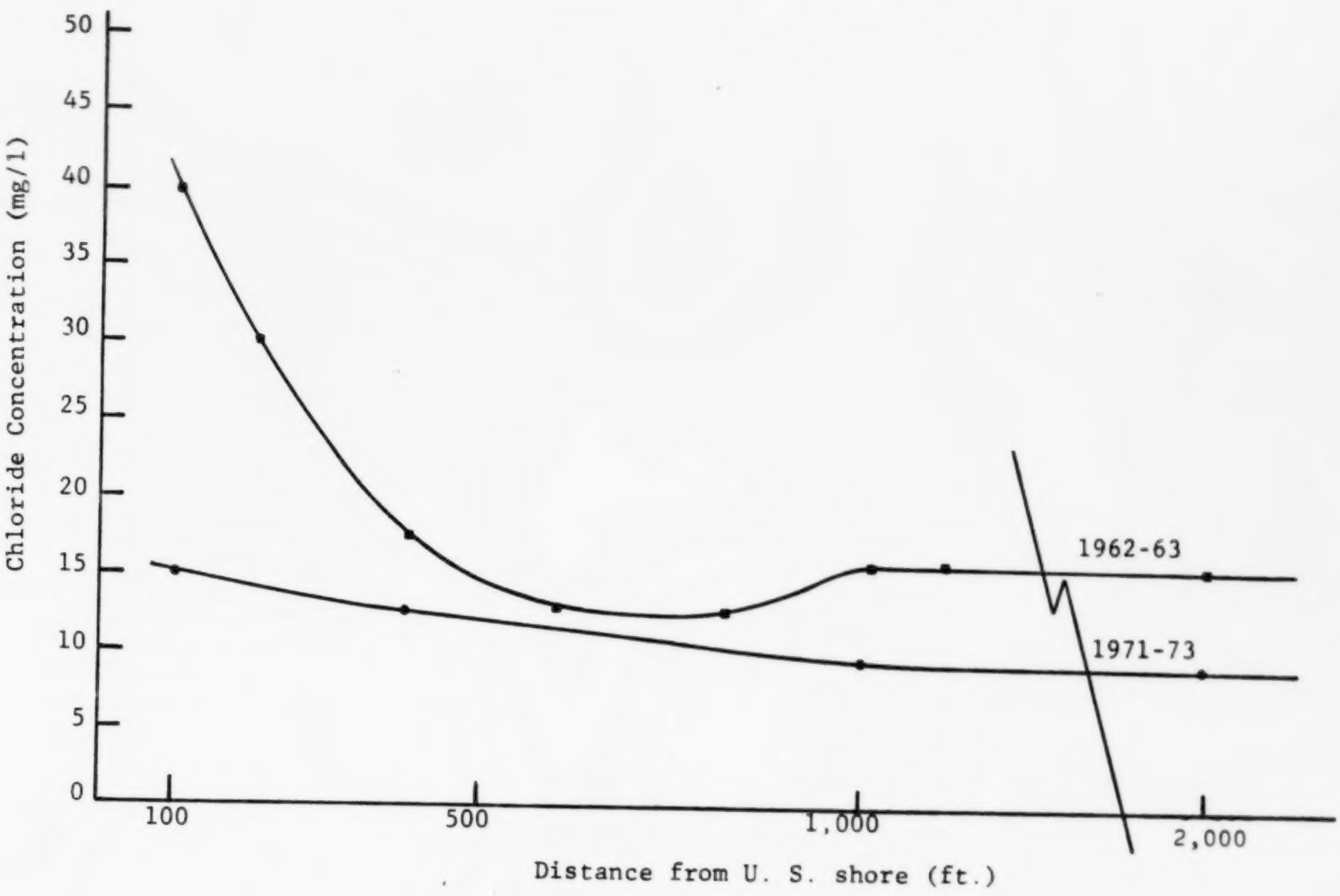


Figure 8. Trends in chloride Concentrations - Detroit River DT 12.0 W

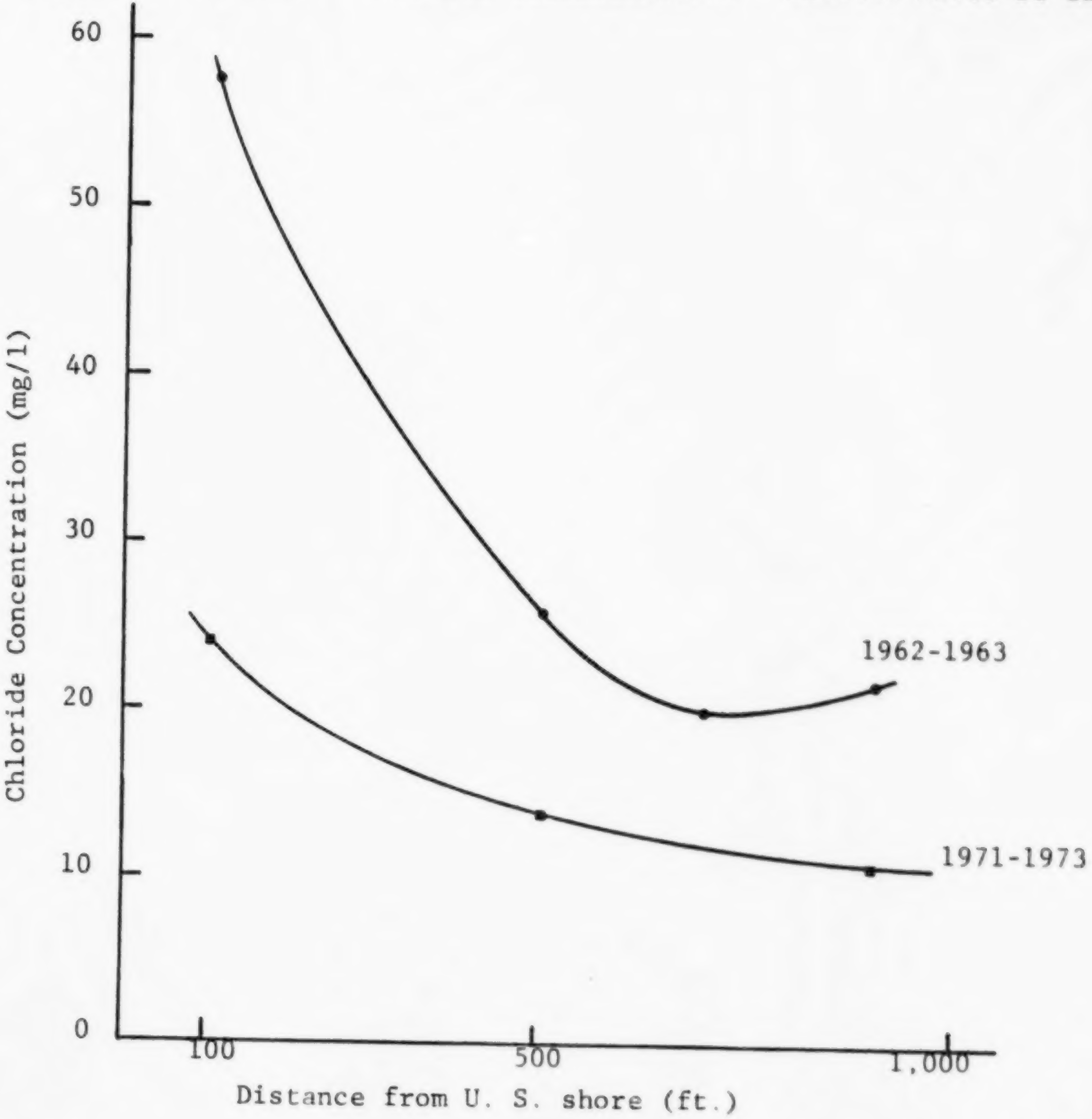


Figure 9. Trends in chloride concentration Detroit River - DT 8.7 W

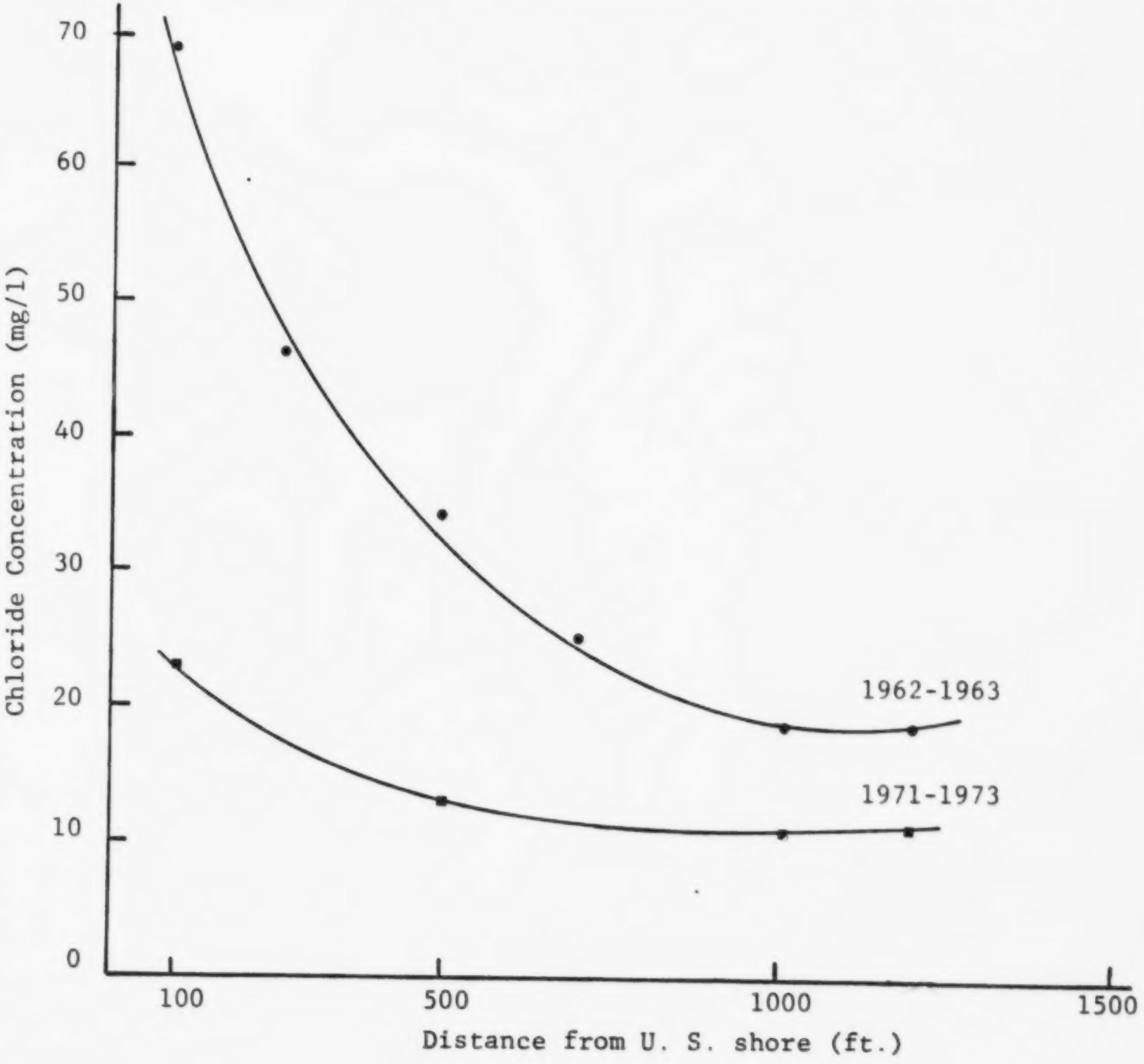


Figure 10. Trends in chloride concentration Detroit River - DT 3.9

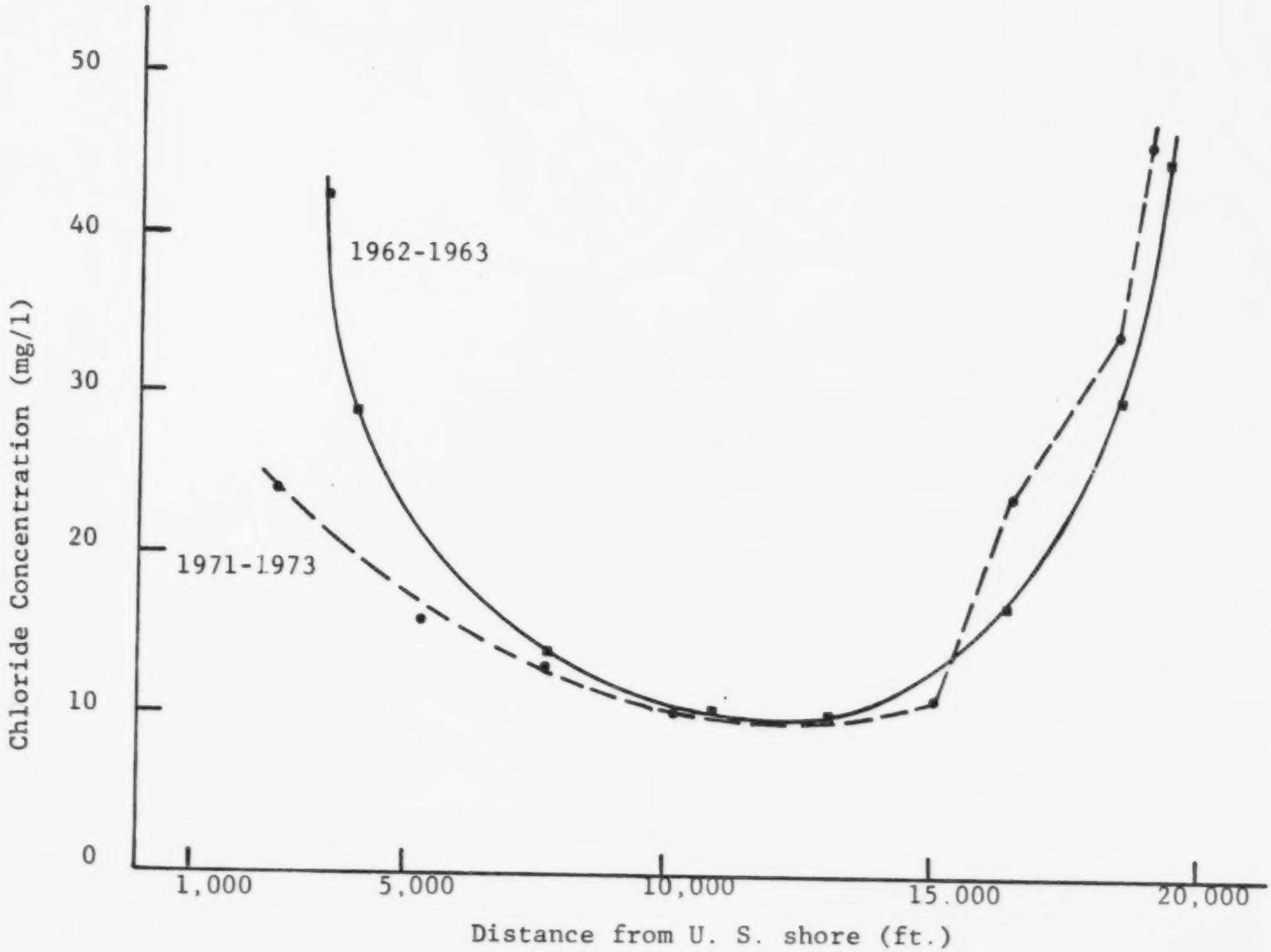


Figure 11. Trends in phenol concentration Detroit River - 8.7 W

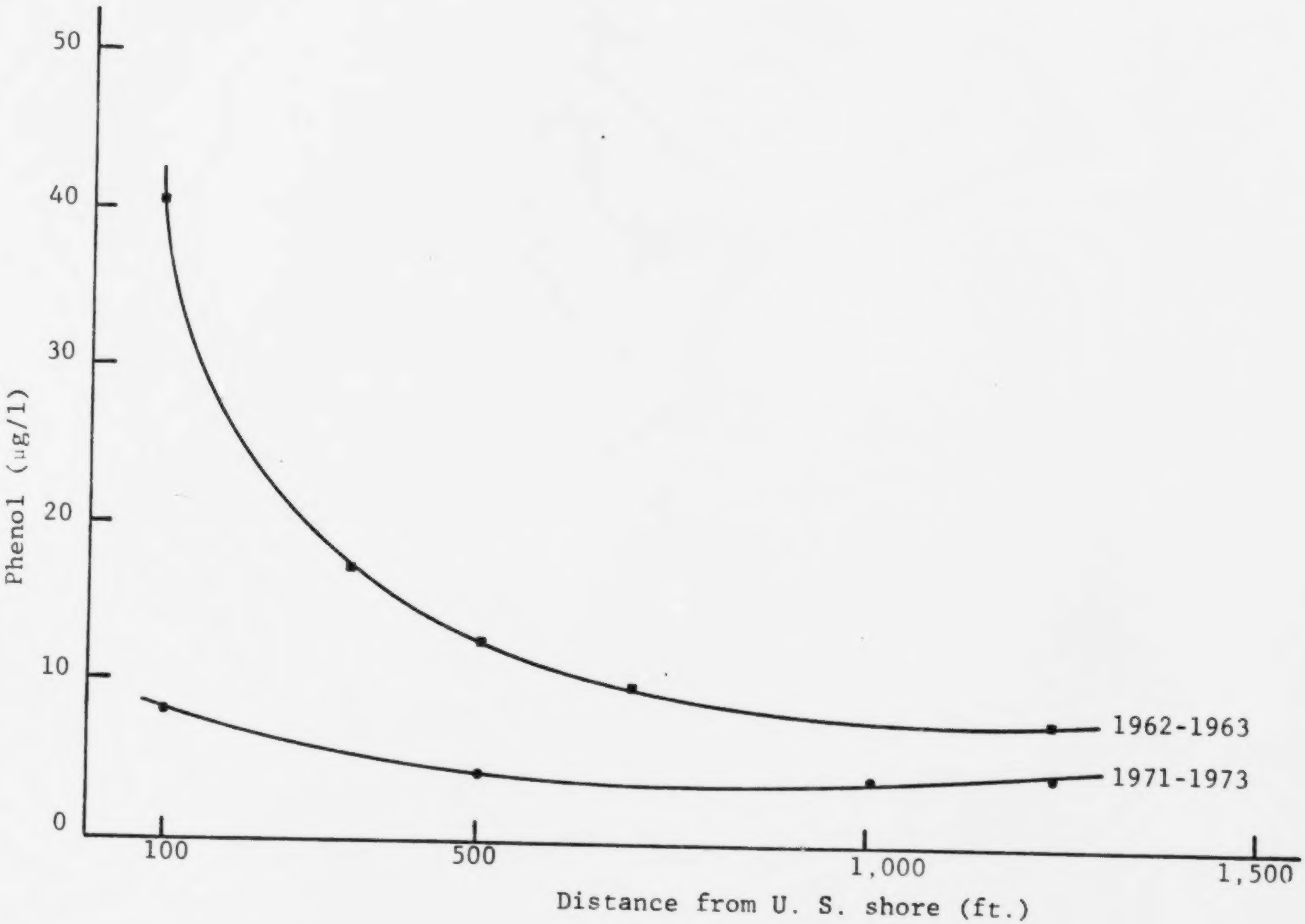


Figure 12. Trends in total coliform concentrations - Detroit River 30.8 W

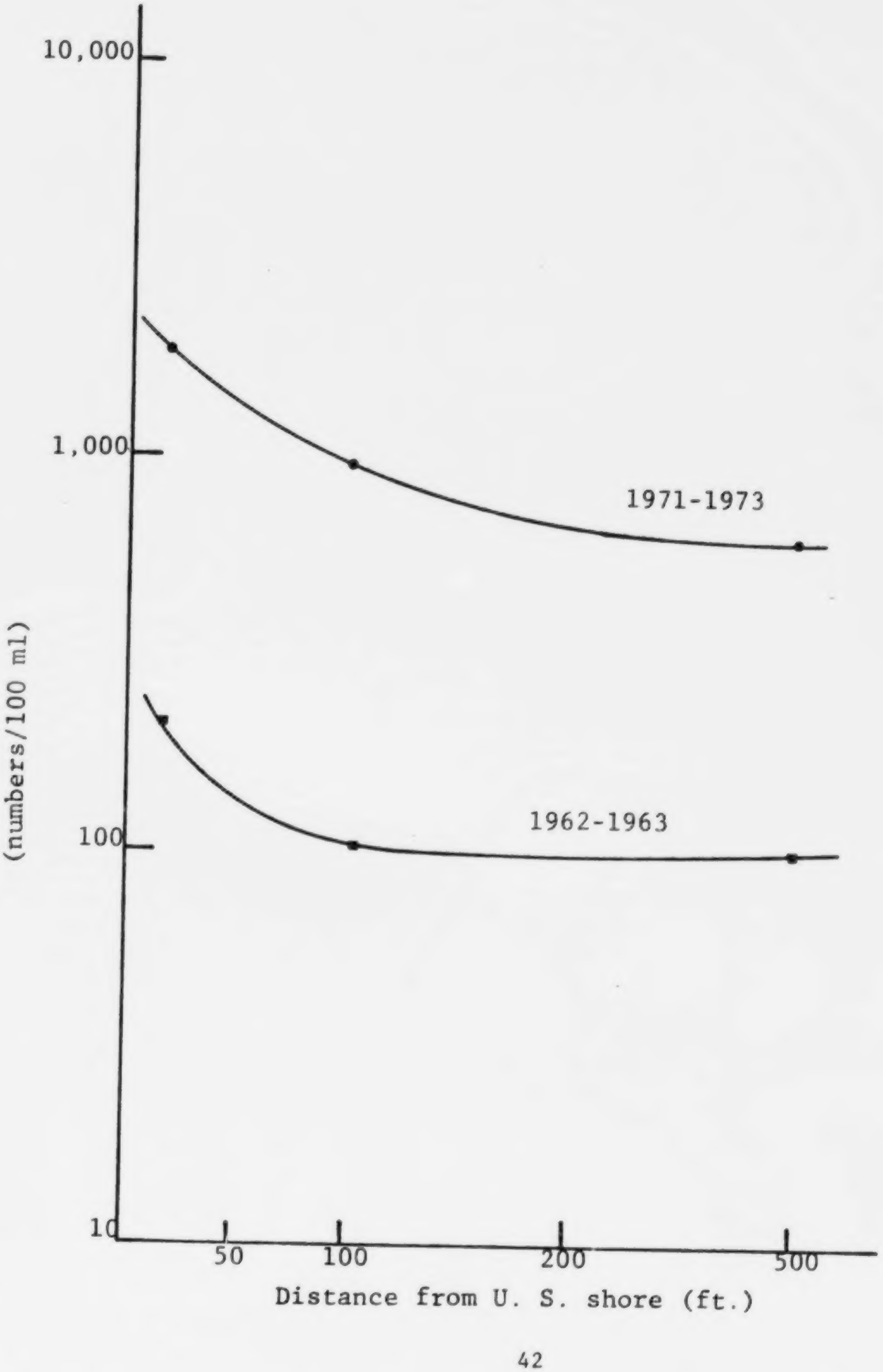


Figure 13. Trends in total coliform concentrations Detroit River DT 20.6

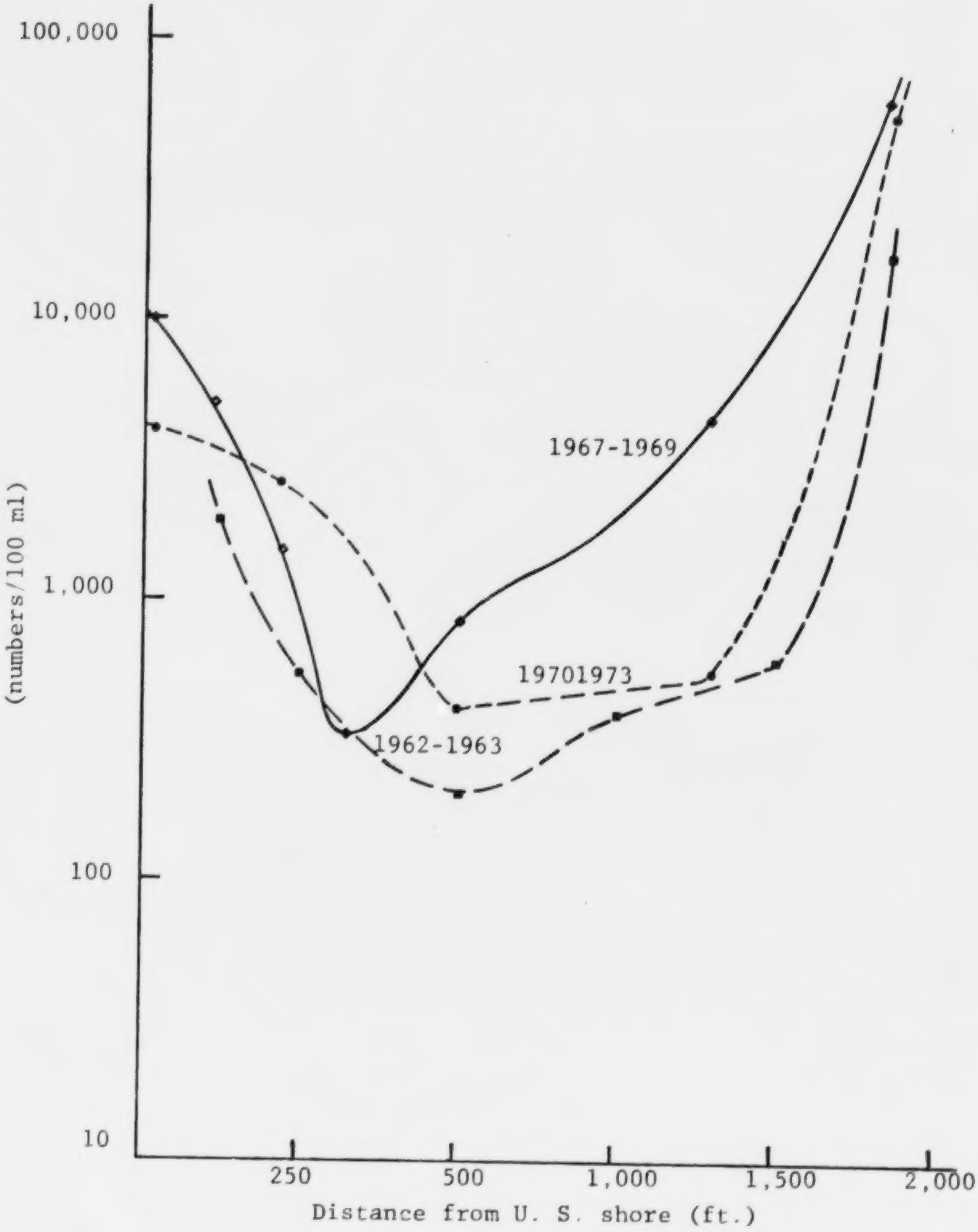


Figure 14. Trends in total coliform concentrations - Detroit River DT 14.6

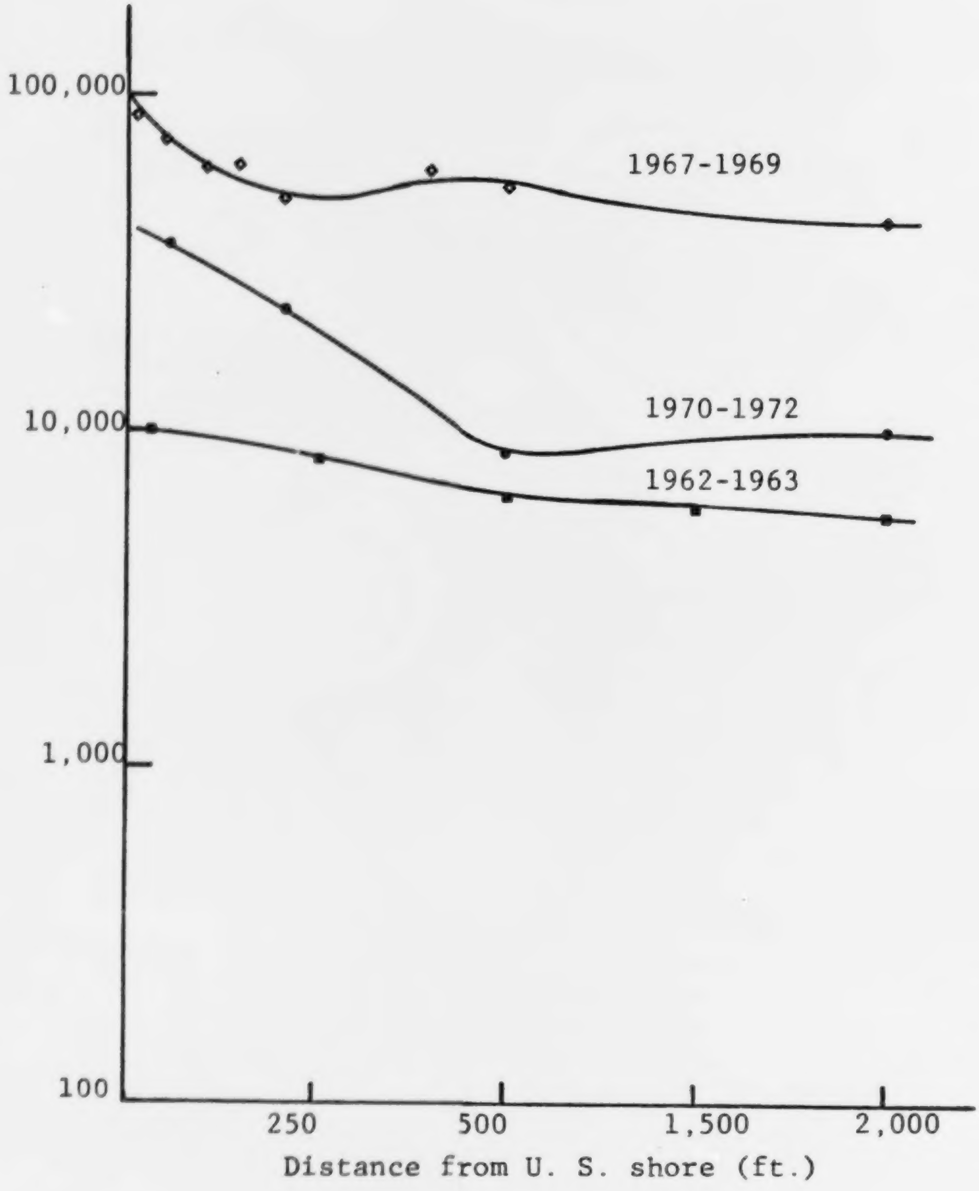


Figure 15. Trends in total coliform concentrations Detroit River 12.0 W

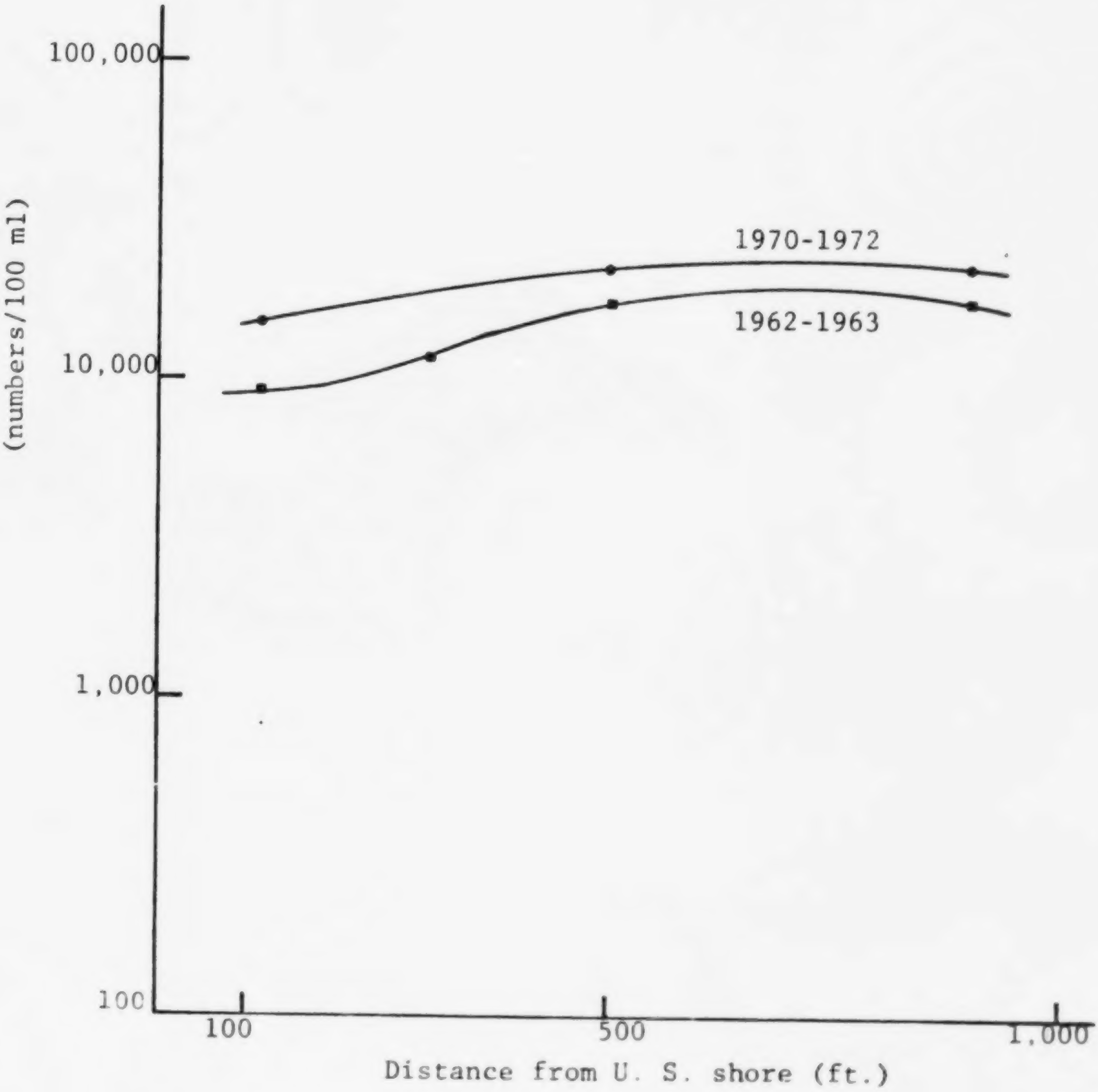


Figure 16. Trends in total coliform concentrations - Detroit River DT 9.3 E

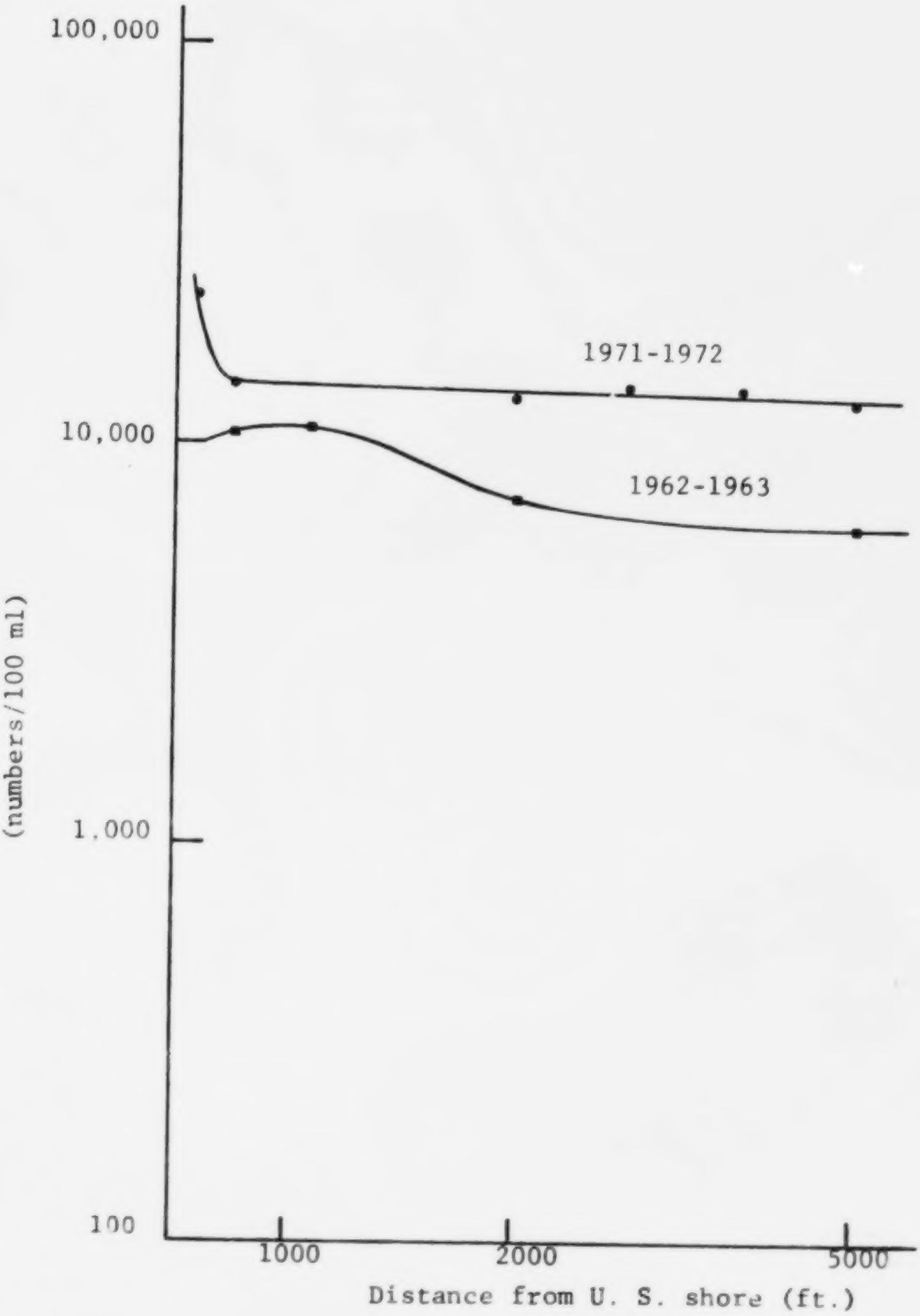


Figure 17. Trends in total coliform concentrations Detroit River DT 8.7 W

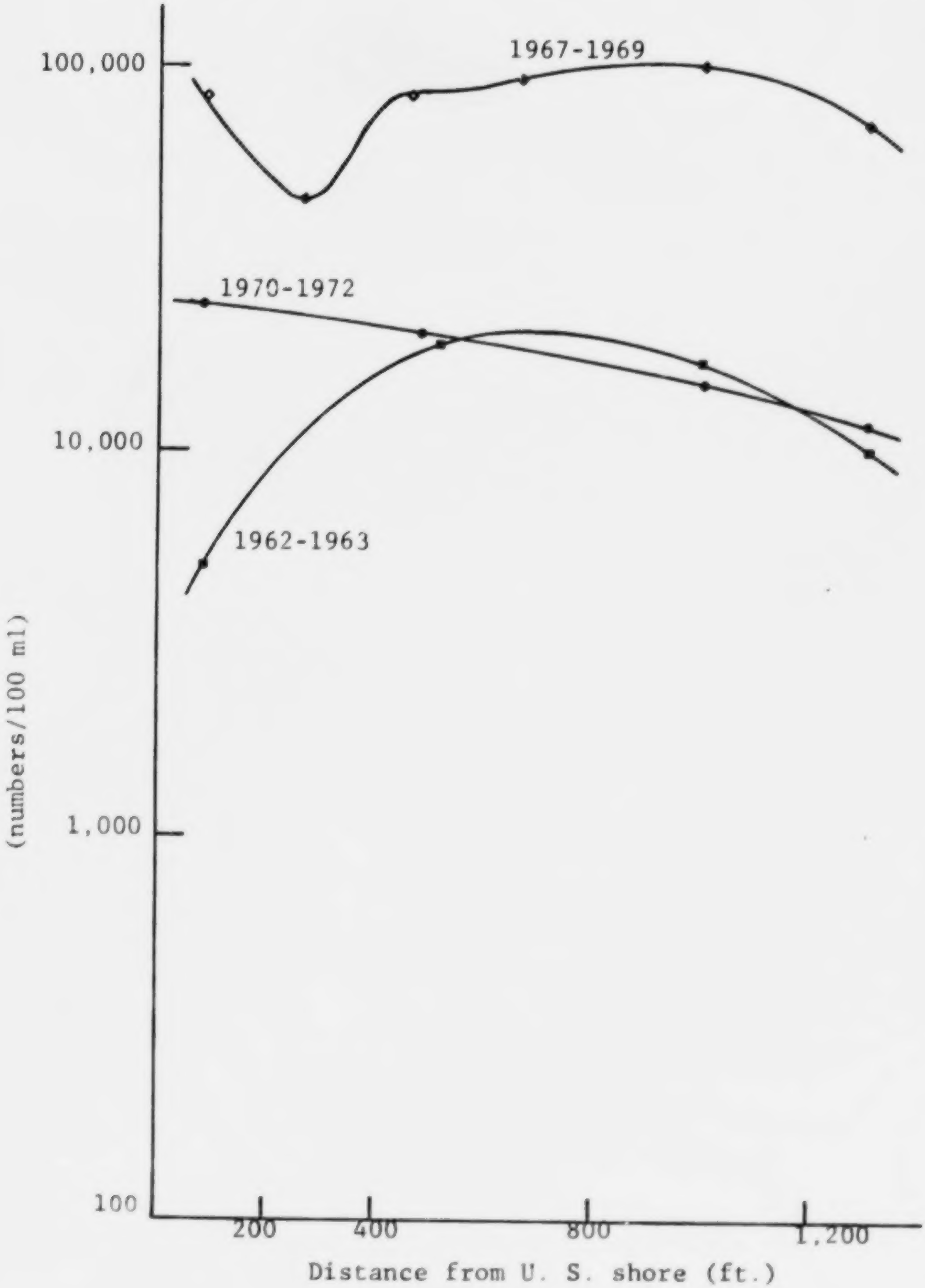


Figure 18. Trends in total coliform concentrations Detroit River DT 3.9

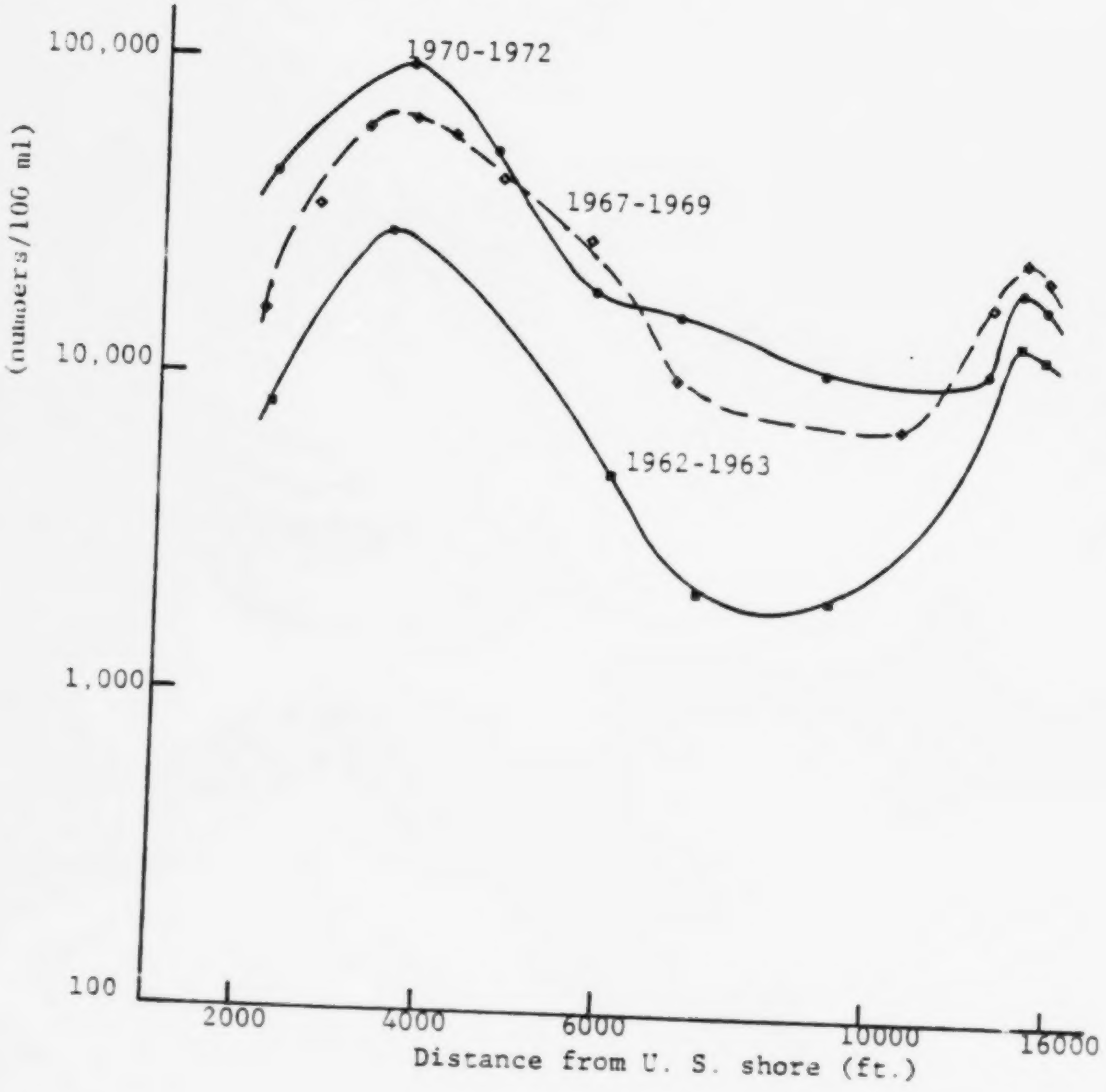


TABLE 8. AVERAGE PHENOL CONCENTRATION- DETROIT RIVER (1962-1973)

Station Milepoint	Feet from U.S. shore	1962-63	1967-69	1971-73
30.0	100	3.5	2.0	1.0
	300	3.5	2.0	1.0
20.6	50	3.7	2.7	1.2
	400	3.5	2.0	1.2
	1000	3.6	2.0	1.2
14.6	100	8.0	5.7	6.7
	400	7.2	4.3	5.9
	1000	4.1	2.0	2.6
12.0W	122	9.0	5.3	5.3
	490	8.2	5.0	4.6
	880	8.5	3.2	3.4
8.7W	80	41.0	21.2	7.4
	480	12.0	6.2	4.8
	980	10.0	4.2	4.6
	1240	7.0	3.7	3.8
3.9	2500	9.5	5.9	5.9
	5500	5.0	3.7	4.0
	7500	3.7	2.3	2.7
	9500	3.2	2.4	1.5
	11500	3.0	2.3	1.0
	15000	3.1	2.1	1.0
	16500	2.7	2.0	1.0
	18500	2.5	2.0	1.1
	19000	2.4	2.0	1.0

Note: all concentrations as ug/l phenol

the average total coliform concentrations appear to be higher for the time periods of 1967-69 and 1970-72 than they were during the early sixties. The overall indication is that the coliform levels increased from the early sixties through the rest of the decade. The concentrations have decreased in the last few years but are still higher than during the Public Health Service Study of 1962.

The International Joint Commission objective for total coliform is 1,000/100 ml. The only stations which met these standards were at milepoint 30.8, and some stations at milepoint 20.6. Thus, even though the trend appears to be a slight decrease in concentrations since 1969, most of the stations are still above the recommended levels.

Nutrients - Ammonia and nitrate nitrogen have been routinely monitored at most stations since 1966, while phosphorus has been monitored routinely since 1968. Prior to these dates only a small amount of scattered information is available. Thus, except for a few stations at milepoints 30.8 and 3.9, sufficient data was available to make an assessment only for the last six or seven years. The data for ammonia, nitrate, and phosphorus is presented in Tables 9, 10, and 11, respectively.

Ammonia nitrogen levels have remained relatively constant for most stations during the last six years. The only stations exhibiting any significant change were those near shore in the Trenton Channel. In this area, as measured at milepoint 8.7W, the concentrations have decreased 20 to 30 percent.

The nitrate concentrations have increased at most stations since 1967. The stations at milepoint 30.8 are only ones which have remained constant during recent years. Some nitrate data for 1964-65 was available for stations at milepoints 30.8 and 3.9. At 30.8 the nitrate levels appear to be 50 percent lower for the 1967-69 period than 1964-65, and since 1967 they have remained constant. At milepoint 3.9 the 1967-69 levels were also lower than those measured in 1964-65. However, the levels have increased since 1967 and are presently as high as, or higher than, the 1964-65 levels.

Phosphorus - Total phosphorus concentrations have decreased at all stations since 1968. Again, the most significant drop has occurred in the Trenton Channel at milepoint 8.7W. Close to 50 percent reduction in phosphorus concentrations has been realized at the near shore station in this area.

Iron - Total iron concentrations have decreased since 1967 at most stations along the river. The near shore stations in the Trenton Channel showed the largest reduction,

TABLE 9. AVERAGE AMMONIA-NITROGEN CONCENTRATIONS - DETROIT RIVER (1963-1973)

Station Milepoint	Feet from U.S. shore	1963-65	1967-69	1969-71	1971-73
30.8	100	.11	.04	0.7	.05
	300	.14	.03	.04	.04
20.6	50		.03	.05	.05
	400		.03	.05	.05
	1000		.05	.08	.07
12.0	122			.46	.45
	490			.16	.19
	880			.08	.10
8.7W	80		.59	.43	.41
	480		.28	.20	.24
	980		.13	.12	.14
	1240		.11	.11	.11
3.9	2500		.57	.60	.55
	5500		.27	.32	.29
	7500		.17	.22	.17
	9500		.06	.07	.09
	11500		.08	.08	.08
	15000		.04	.03	.05
	16500		.03	.04	.05
	18000		.03	.05	.07

Note: All concentrations are mg/l as Nitrogen

TABLE 10. AVERAGE NITRATE NITROGEN CONCENTRATIONS - DETROIT RIVER (1964-1973)

Station Milepoint	Feet U.S. Shore	1964-65	1967-69	1969-71	1971-73
30.8W	100	.23	.12	.12	.13
	300	.22	.14	.11	.10
20.6	50		.09	.11	.17
	400		.10	.12	.16
	1000		.10	.12	.15
14.6	100		.25	.38	.51
	400		.18	.25	.26
	1000		.16	.20	.21
12.0W	122			.26	.31
	490			.20	.26
	880			.17	.24
8.7W	80		.29	.41	.43
	480		.23	.35	.37
	980		.17	.22	.26
	1240		.20	.24	.24
3.9	2500		.34	.64	.63
	5500	.25	.20	.32	.46
	9500	.22	.15	.18	.25
	11500	.21	.15	.20	.22
	15000	.20	.15	.16	.20
	16500	.20	.17	.16	.18
	18500	.26	.20	.19	.23

Note: All concentrations are mg/l Nitrogen

TABLE 11. AVERAGE TOTAL PHOSPHOROUS CONCENTRATION - DETROIT RIVER (1968-1972)

Station Milepoint	Feet from U.S. Shore	1968-70	1970-72
30.8W	100	.16	.06
	300	.08	.05
20.6	50	.13	.10
	400	.07	.06
	1000	.10	.08
14.6	100	.18	.13
	400	.16	.11
	1000	.09	.07
12.0W	122	.24	.18
	490	.15	.12
	880	.11	.10
8.7	80	.41	.22
	480	.23	.15
	980	.17	.13
	1240	.16	.12
3.9	2500	.36	.24
	5500	.22	.17
	7500	.15	.13
	9500	.12	.08
	11500	.08	.06
	15000	.07	.05
	16500	.07	.04
	18500	.08	.04

Note: All concentrations as mg/l as Phosphorous presumably due to increased industrial pollution control. The total iron data is given in Table 12. It can be seen in this table that the iron concentrations below DT 14.6, exceed the present standards.

Dissolved Solids - Dissolved solids information is only available for 1971 through 1973 at most stations. During this short period, however, all stations have shown an increase in total dissolved solids concentrations. In some cases these increases are greater than 20 percent. Even though this parameter has only been routinely monitored for the past three years, the indication is that the levels are continually increasing, however they are well within established standards. Data for dissolved solids is presented in Table 13.

Cyanide - Cyanide has been monitored for several years because of its potential toxic effect on the river. Except for a few instances in the early sixties, cyanide concentrations have remained constant in the river at a level of approximately 0.01 mg/l.

Statistical results - The results of statistically evaluating the mean annual values for 1968 and 1973 for the Detroit River are presented in Table 14. Chlorides were observed to have decreased significantly at two stations, both relatively near the United States shore at milepoints 12.0W and 3.9. Iron concentrations also decreased at three stations on these two transects. The nitrate concentration was observed to have increased at three stations in the downriver region. The most important results were observed with respect to the phosphorus concentration which has decreased significantly at nearly all stations below milepoint 12.0W. No statistically significant changes were observed with respect to total coliform and ammonia nitrogen concentrations between these two years.

Summary - In general, the water quality of the river has improved over the past ten years. The chloride, phenol, phosphate, and iron concentrations have all decreased. The past four years have shown signs that the coliform levels may be dropping, although more time will be required to determine if this trend will continue. The decrease in concentration of these parameters appears to indicate that the industrial and combined sewer overflow control programs are beginning to have a positive effect on the river water quality.

TABLE 12. AVERAGE TOTAL IRON CONCENTRATIONS - DETROIT RIVER (1967-1973)

Station Milepoint	Feet from U.S. Shore	1967-69	1969-71	1971-73
30.8	100	513	431	264
	300	372	355	297
20.6	50	399	480	415
	400	333	365	278
	1000	311	373	263
14.6	100	854	692	641
	400	614	650	571
	1000	507	493	389
12.0W	122		789	719
	490		698	610
	880		484	490
8.7W	80	1240	1145	918
	480	1079	858	642
	980	733	633	548
	1240	568	581	496
3.9	2500	980	826	706
	5500	804	597	600
	7500	668	526	502
	9500	574	421	421
	11500	538	408	358
	15000	550	376	297
	16500	564	475	354
	18500	643	529	587

Note: All concentrations are ug/l as Iron

TABLE 13. AVERAGE DISSOLVED SOLIDS CONCENTRATIONS - DETROIT RIVER (1971-1973)

Station Milepoint	Feet from U.S. shore	1971	1972	1973
30.8	100	133	134	168
	300	127	143	165
20.6	50	129	132	162
	400	123	116	158
	1000	121	119	160
14.6	100	139	151	187
	400	141	150	163
	1000	132	138	152
	2000	131	139	153
12.0	122	166	175	192
	490	148	148	162
	880	136	149	165
8.7 W	80	167	182	193
	480	143	140	168
	980	142	139	167
	1240	137	148	170
3.9	2500	173	192	188
	5500	151	164	163
	7500	140	162	162
	9500	129	153	162
	11500	125	150	157
	14500	130	145	158
	16500	155	197	180
	18500	189	212	218
	19000	230	245	210

Table 14. STATISTICAL EVALUATION OF MEANS - DETROIT RIVER 1968 versus 1973

River mile	Distance from shore (ft.)	Chlorides	Phenols	Nitrates	Phosphates	Iron
30.8 W	100	-	-	-	-	-
	300	-	-	-	1968>1973	-
20.6	50	-	-	-	-	-
	400	-	-	-	-	-
	1000	-	-	-	-	-
14.6	100	-	-	-	-	-
	400	-	-	-	-	-
	1000	-	-	-	-	-
12.0 W	122	1968>1973	-	-	1968>1973	1968>1973
	490	-	-	1968<1973	-	1968>1973
	880	-	-	-	-	-
8.7 W	80	-	-	-	-	-
	480	-	-	-	1968>1973	-
	980	-	-	1968<1973	-	-
	1240	-	-	-	1968>1973	-
3.9	2500	-	1968<1973	-	1968>1973	-
	5500	1968>1973	-	-	-	-
	7500	-	-	1968<1973	1968>1973	-
	9500	-	1968>1973	-	1968>1973	1968>1973
	11500	-	-	-	1968>1973	-
	15000	-	-	-	1968>1973	-
	16500	-	-	-	-	-
	18500	-	-	-	1968>1973	-
	19300	-	-	-	1968>1973	-

SECTION V

WATER QUALITY SURVEY

INTRODUCTION

Methodology

Field investigations were made during three seasonal periods, with surveys performed on August 14-16, 1973 (summer period), November 6-8, 1973 (fall period) and May 13-15, 1974 (spring period). A 42 foot, steel-hulled vessel was equipped with the necessary cranes, winches, and other sampling equipment for the survey operation. Due to the extended range of the study area, each survey required three days for completion. In order to insure the reliability of the analytical results, samples were returned to the laboratory at the end of each day for analysis of those parameters which could not be determined in-situ at each sampling location.

Station transects across the river were located by means of conspicuous landmarks. Distances from shore were measured by a visual rangefinder in order to determine when the survey vessel was on station.

Station Locations

The specific sampling stations to be surveyed were chosen on the basis of the historical data base for the area, existence of on-going monitoring programs or surveys by other groups, presence of significant wastewater inputs, and required information for the modeling effort. As discussed earlier, the State of Michigan and the Province of Ontario have programs of comprehensive water quality monitoring for both the St. Clair and Detroit Rivers. The cross river transects to be used for this study were thus chosen to coincide with those established and monitored by the agencies of these governments. Since budgetary restrictions precluded sampling at all stations maintained by these agencies, the stations surveyed at each selected transect were chosen to provide a representative overview of each transect area. The stations selected and numbering system followed are presented in Table 15 and Figure 19.

TABLE 15. STATION LOCATIONS

Station No.	River Transect (mile point)	Distance from Western Shore (ft.)	Station Description
1	SR 39.0	400	St. Clair R. at mouth of Lake Huron
2	SR 39.0	800	St. Clair R. at mouth of Lake Huron
3	SR 13.7	400	St. Clair R. near Algonac
4	SR 13.7	1,400	St. Clair R. near Algonac
5	DT 30.8	100	Detroit River west of Peach Island
6	DT 30.8	1,000	Detroit River west of Peach Island
7	DT 30.7	900	Detroit River east of Peach Island
8	DT 20.6	50	Detroit River app. 3,400 ft. south of Ambassador Bridge
9	DT 20.6	1,000	Detroit River app. 3,400 ft. south of Ambassador Bridge
10	DT 19.0	100	Detroit River at mouth of Rouge River
11	DT 19.0	2,500	Detroit River at mouth of Rouge River
12	DT 17.0 E	900	Detroit River at east side of head of Fighting Island
13	DT 16.0 W	100	Detroit River below mouth of Ecorse River
14	DT 16.0 W	4,000	Detroit River below mouth of Ecorse River
15	DT 14.6 W	100	Detroit River west side of tip of Grosse Ile
16	DT 11.5	1,200	Detroit River east of Grosse Ile at mouth Rivier Aux Canards
17	DT 11.5	4,000	Detroit River east of Grosse Ile at mouth Rivier Aux Canards

TABLE 15. STATION LOCATIONS (cont.)

Station No.	River Transect (mile point)	Distance from Western Shore (ft.)	Station Description
18	DT 8.7	80	Detroit River in Trenton Channel at Elizabeth Park
19	DT 3.9	2,500	Mouth of Detroit River
20	DT 3.9	5,500	Mouth of Detroit River
21	DT 3.9	13,000	Mouth of Detroit River
22	DT 3.9	16,500	Mouth of Detroit River

Figure 19. Sampling station locations

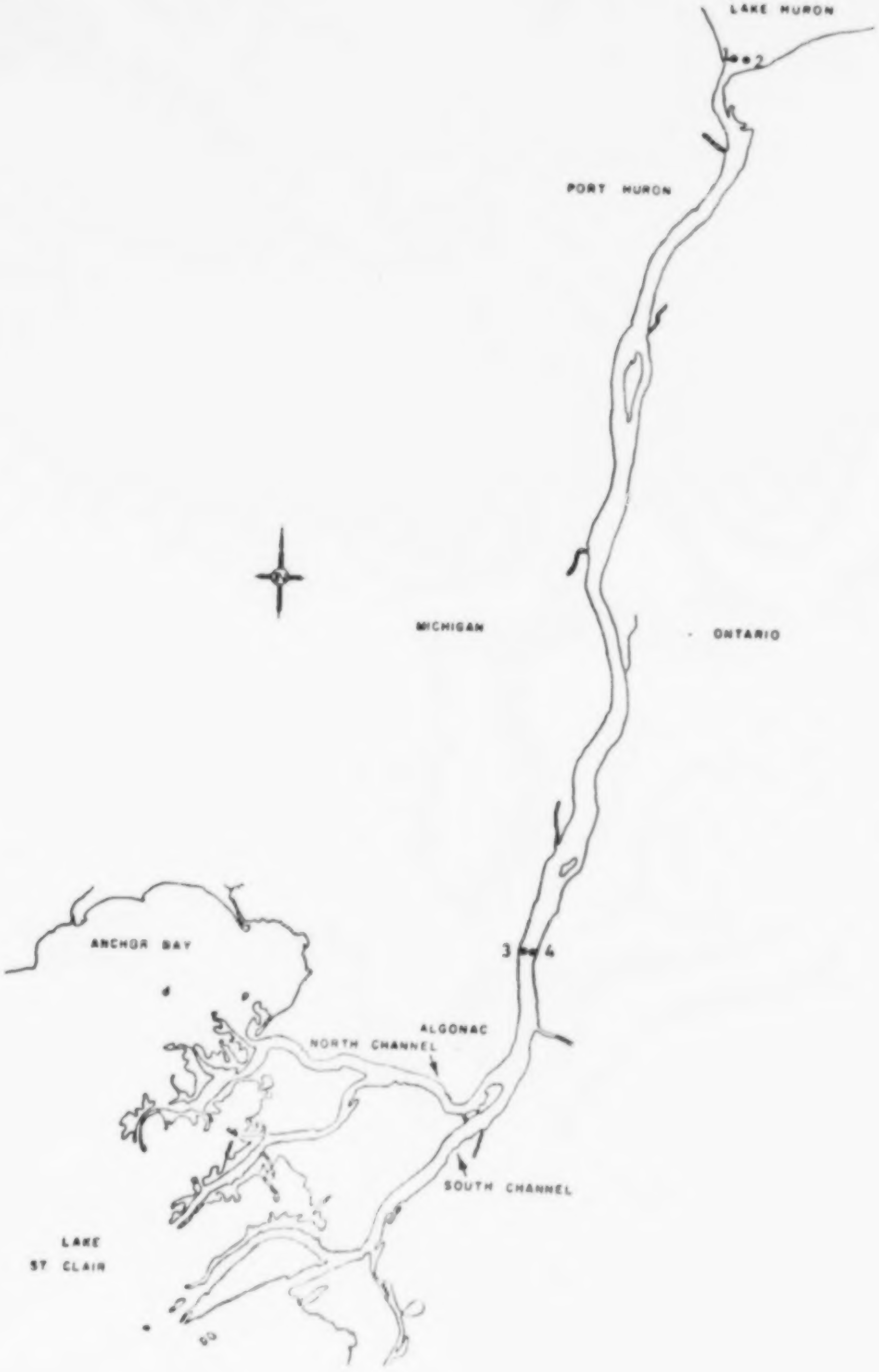

LAKE HURON
1
2
PORT HURON
MICHIGAN
ONTARIO
3
4
ANCHOR BAY
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 19.(cont.). Sampling station locations

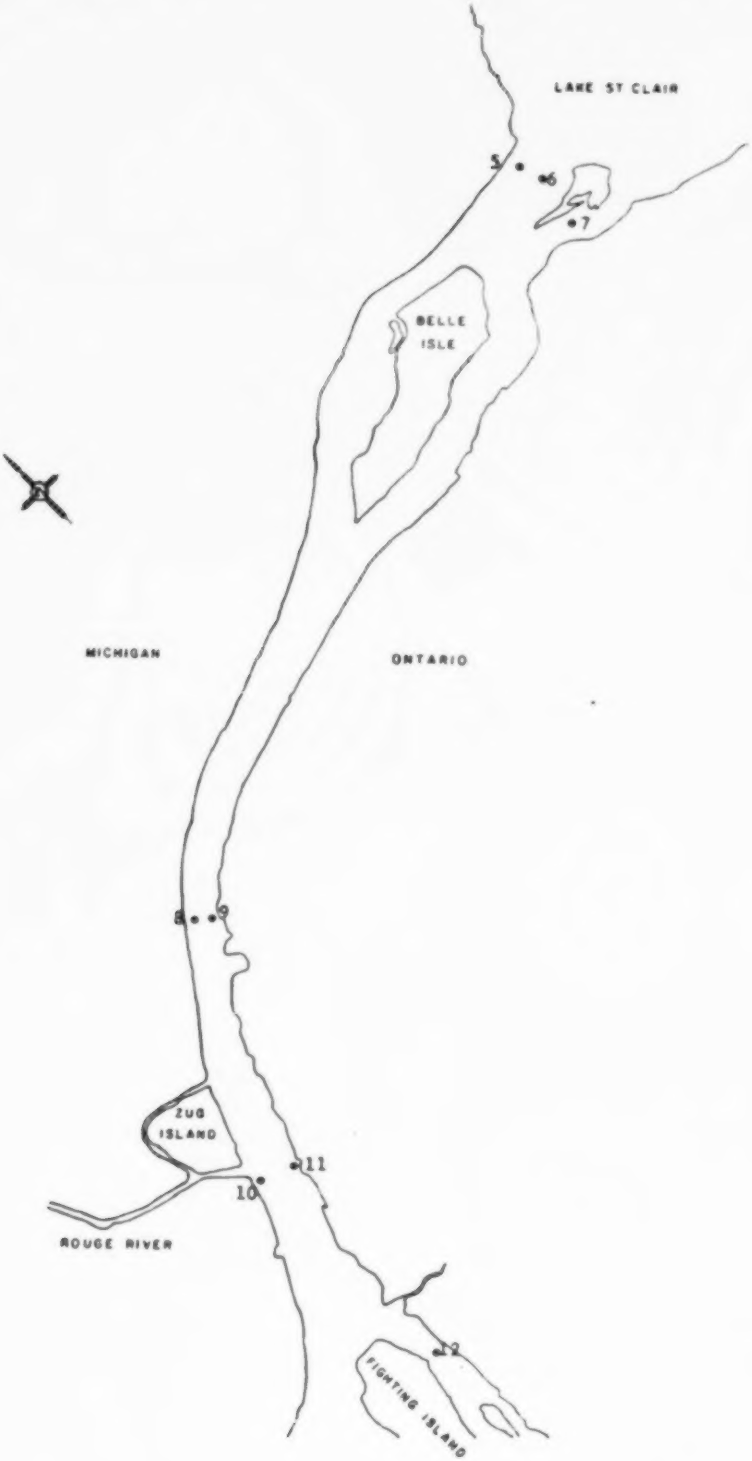
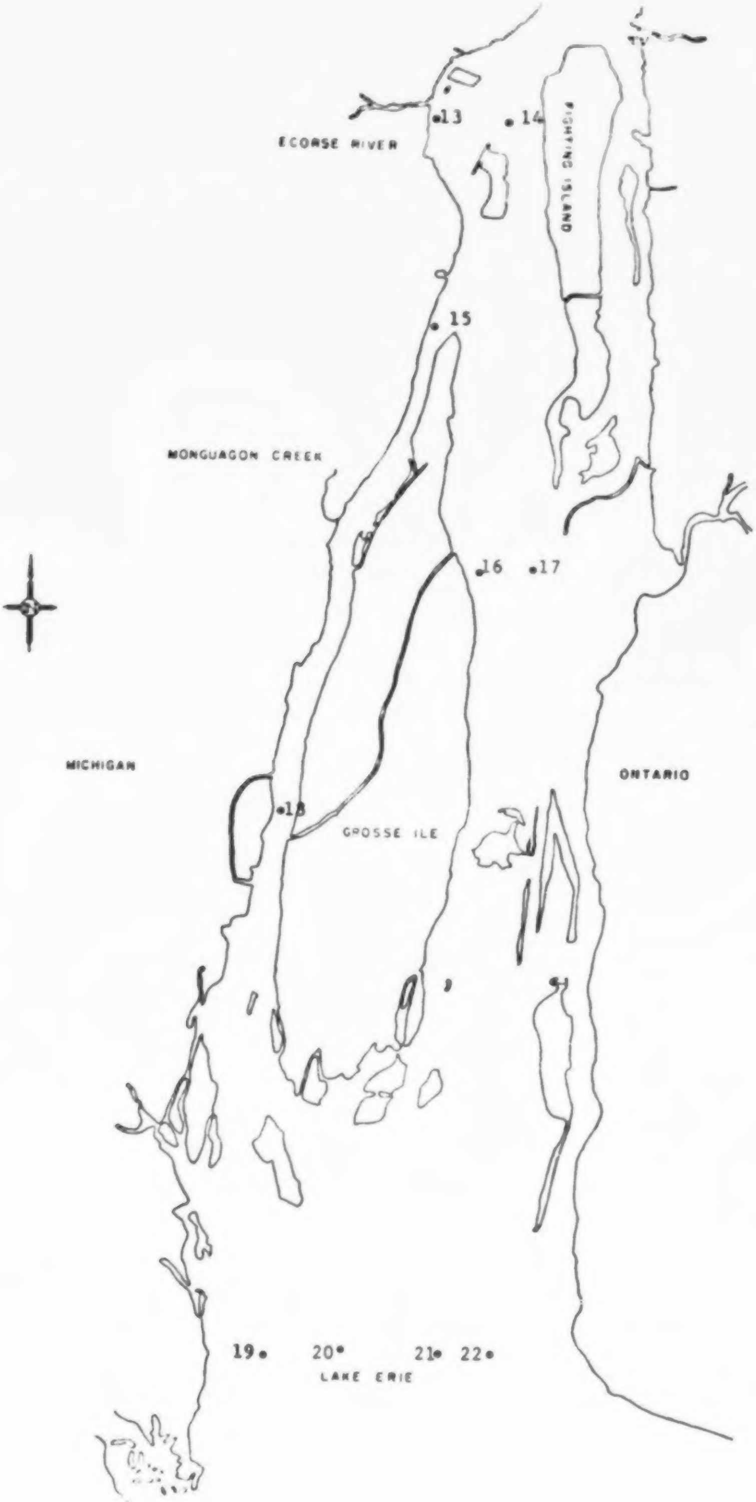

LAKE ST CLAIR
5
6
7
BELLE ISLE
N
MICHIGAN
ONTARIO
8
9
ZUG ISLAND
11
10
ROUGE RIVER
12
FIGHTING ISLAND

Figure 19.(cont.). Sampling station locations


13
14
ECORSE RIVER
FIGHTING ISLAND
15
MONGUAGON CREEK
16
17
MICHIGAN
ONTARIO
18
GROSSE ILE
19
20
21
22
LAKE ERIE

CHEMISTRY

Introduction

The existing monitoring program of the various governmental agencies provide a great deal of information with respect to the more common water quality parameters, such as oxygen demanding carbonaceous material (BOD and COD), nutrients (nitrogen and phosphorus species) and some specific toxic materials and heavy metals (iron, phenol and cyanide). Parameters which have received little attention include the broader range of heavy metals and pesticides in the aqueous phase, as well as the entire range of materials present in the sediment phase.

The objective of surveys performed as a portion of this study was the closing of gaps and deficiencies in the existing data base, as well as providing verification of existing data. Consequently, the chemical portion of the survey encompassed three basic elements: an analysis of the aqueous phase, including a broad spectrum of metal ions and pesticides in addition to the more common water quality parameter;evaluation of the heavy metal, nutrient, and organic content of the sediment; and a preliminary determination of the potential for this same material to be released from the sediment into the aqueous phase.

Methodology

Field Sampling ·

Insitu measurements of dissolved oxygen, temperature, and specific conductance were made at measured depths using a remote sensing probe cluster. The oxygen sensing device was of the polarographic type electrode utilizing a fluorocarbon semipermeable membrane. The sensing unit was fitted with an agitation device which precluded an oxygen concentration gradient around the probe. The variation in partial pressure of oxygen as a function of temperature and depth was compensated for internally by the device. The thermistor in this oxygen probe was used to sense water temperature and data readout was made on the same meter by means of switch selection. Insitu measurement of specific conductance was accomplished through the use of a remote sensing platinum conductivity cell. Data output was by the direct-reading meter. For all insitu measurements, depth was determined by calibration of the probe cluster supporting cable.

Water samples for laboratory analysis were taken with a two liter vertical Van Dorn bottle.

Samples were obtained from the surface, approximately half the total river depth, and approximately one meter from the river bottom, and composited in nonmetallic vessels for subsequent distribution to proper transport and storage containers. The fraction of sample for analysis of the Biochemical Oxygen Demand was transferred immediately to an incubation bottle and refrigerated until it was transported to the laboratory at the end of the day. Sample fractions for Chemical Oxygen Demand were transferred to glass containers and were preserved with sulfuric acid (1 ml H_2SO_4 per 100 ml sample) and refrigerated. One liter fractions of the composite samples were transferred to linear polyethylene containers and preserved with nitric acid (1 ml HNO_3 per 100 ml sample) for subsequent metal ion analysis. Four liter sample fractions were drawn for the analysis of chlorinated organics. These samples were stored in reagent quality glass containers with teflon liners and refrigerated at 4^oC until analysis was initiated.

A gravity stratification corer was the primary means for procuring sediment samples, although during the first survey a Ponar dredge was employed where satisfactory core samples could not be obtained. Since samples obtained by the Ponar dredge are more disturbed than those obtained by means of the coring device, efforts were made to reduce the need for the Ponar. Consequently, for the second and third surveys, the coring device was modified to provide positive sample recovery whenever the bottom material was appreciably penetrable. The corer was finned and weighted and outfitted with a positive retention coring head. The coring tube itself was lined with a removable polycarbonate sleeve so that core samples could be removed essentially untouched. Upon removal of the sample, the sleeve was fitted with water-tight end caps so that no loss of interstitial liquid would occur prior to analysis.

Sediment samples taken by either device were refrigerated on board ship until they could be transported to the laboratory at the end of each sampling day. Upon receipt in the laboratory they were frozen and stored at minus 20^oC until analysis was initiated.

Analytical Procedures

In general, all methods of chemical analysis were taken from widely approved compilations of analytical procedures[9-14]. Where methods were unavailable or insufficient to provide the desired information, alternate analytical procedures were employed after their accuracy and precision had been statistically verified. A brief synopsis of the analytical methodology is contained in the paragraphs that follow.

Aqueous phase - Aqueous samples for the analysis of five-day Biochemical Oxygen Demand

(BOD_5) were allowed to warm from their refrigerated condition and to equilibrate with respect to oxygen concentration at 20° C. Initial dissolved oxygen levels were determined, the vessels were sealed, and the samples were incubated in the dark for five days at 20° C. Final oxygen levels were measured after this incubation period and the BOD_5 was calculated. All dissolved oxygen determinations were made by means of a polarographic electrode device.

The analysis of Chemical Oxygen Demand (COD) in the water samples was accomplished through the standard potassium dichromate-sulfuric acid reflux method. The dichromate oxidant was 0.025 N in concentration.

Total concentrations of the metals cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc were determined in acidified water samples. High temperature flameless atomic absorption spectrophotometry was employed for all metals except mercury, nickel, and zinc. Mercury was analyzed using the cold vapor atomic absorption technique of Hatch and Ott[15]. Nickel and zinc were analyzed using conventional air-acetylene flame atomic absorption spectrophotometry. The method of standard addition was utilized throughout in order to compensate for matrix effects on instrument calibration.

The analysis of water samples for chlorinated organic species was performed in accordance with the procedures outlined by the Environmental Protection Agency[11]. The samples were triple extracted with 15 percent (v/v) ethyl ether in hexane and the extracts dried with anhydrous sodium sulfate. (All solvents used in the characterization of organic species were of "Distilled in Glass" quality purchased from Burdick and Jackson, Muskegon, Michigan.) The extracts were then concentrated and transferred to the top of a column of florisil (activated at 550 °C for 24 hours). The chlorinated species were eluted with 15 percent ethyl ether in hexane and again concentrated. The concentrations were then subjected to analysis by vapor phase chromatography utilizing an electron capture detector. The resultant peaks were integrated either together or discretely to provide either "total chlorinated hydrocarbon" levels or the concentration of individual pesticide species. Calibration of instrument response was accomplished using external standards.

Sediment phase - Sediment samples were thawed and extruded from the polycarbonate sleeve in preparation for subsequent analyses. Physical descriptions were noted while the sediment was wet. Where core samples were available, the top five centimeter section was isolated, weighed and placed in an evaporating dish to air dry to constant weight. In the case of Ponar grab samples, the entire sample was homogenized while wet and a 200 gram subsample was weighed, transferred to an evaporating dish, and air dried. After the dry weights were recorded, all sediment samples were ground with a mortar and pestle. Stones larger than five mm were manually excluded. No distinct sieving of the sediment was undertaken.

The analysis of carbonaceous material in the sediments included the determination of COD using the potassium dichromate-sulfuric acid digestion method[11]. Volatile solids were determined by ashing the samples at 550° C for 24 hours. Kjeldahl nitrogen was measured by the digestion-distillation-titration technique[10,14]. Nitrate-nitrogen was obtained by refluxing the sediment in acid media followed by filtration and reaction with Brucine sulfate under the controlled temperature conditions of the extended Brucine method[10,14]. Total phosphorus was determined by vanadomolydophosphoric acid test following a persulfate-sulfuric acid digestion.

Sediment samples for metal analysis (with the exception of mercury) were prepared by dry ashing at 550 °C for 24 hours, acid leaching the residue with a nitric acid - hydrogen peroxide solution, and removing the undissolved residue by filtration. The filtrate was analyzed for cadmium, chromium, copper, iron, lead, manganese, nickel and zinc using conventional air-acetylene flame atomic absorption spectrophotometry. Mercury analysis was accomplished using a wet digestion of the sediment[16]. The finely divided samples were allowed to react overnight with fuming nitric acid and potassium dichromate. Excess hydroxylamine hydrochloride was then added and the sample vessel was degassed. Reduction of the mercury with stannous chloride was followed by detection of the elemental mercury using the cold vapor atomic absorption method[15].

Sediment samples for analysis of chlorinated organic species were taken after they had air dried to constant weight at room temperature (approximately 25°C). An eight hour soxhlet extraction was performed using chloroform as the solvent. The extract was evaporated to dryness on a water bath to remove the chloroform. Caution was exercised to prevent excessive drying which could result in degradation of the pesticides. The residue was taken up in 15 percent (v/v) ethyl ether in hexane and the fractions were collected and concentrated for final detection by electron capture vapor phase chromatography. Calibration was accomplished by means of external standards. Extraction and clean-up recoveries were verified using spiked samples.

Sediment exchange experiments - In order to gather preliminary information on the potential for component exchange from the bottom sediments to the aqeuous phase, a 10 gram sample of dried sediment was agitated in an air-tight vessel containing 250 ml of exchange water. This exchange water for samples from the first survey consisted of deoxygenated distilled water. However, the lack of hardness and alkalinity in this water resulted in unrealistic exchange levels and subsequently, exchange experiments for the final two surveys utilized a synthetic "river water". This synthetic exchange water contained 100 mg/l calcium hardness and sufficient alkalinity to buffer the system to pH 8.25. Such concentrations approximate fairly closely the major constituents in the St. Clair and Detroit River waters. Throughout all the exchange studies, the dissolved oxygen of the exchange water was intentionally less than 0.5 mg/l in order to simulate the most favorable conditions for exchange - that is, anaerobic conditions - as well as the conditions which are likely to exist in the river sediments.

The sealed exchange vessels were agitated on a reciprocating shaker (10 cm strokes, 100 cycles per minute) for 10 days at room temperature. The samples were then allowed to settle for 24 hours and the supernatant was decanted off. No centrifugation or filtration was employed to remove suspended particulates. Aliquots of the supernatant were used for subsequent chemical analysis.

The COD of the exchange water was determined by the potassium dichromate-sulfuric acid digestion procedure. Total phosphorus was measured using acid digestion procedure. Total phosphorus was measured using the persulfate-sulfuric acid digestion and vanadomolybdophosphoric acid detection. Nitrate-nitrogen was measured after refluxing in acid media through the extended Brucine method. Kjeldahl-nitrogen in the exchange water was isolated by the standard digestion and distillation procedures. However, in order to provide sufficient sensitivity, the detection of this nitrogen form was accomplished with an ammonia gas sensing electrode[17,18].

The metal concentrations in the exchange water were determined by atomic absorption spectrophotometry. Cadmium, chromium, copper, iron, lead, manganese, nickel, and zinc were all determined after digesting the exchange samples with nitric acid and hydrogen perioxide. Mercury was not determined in the exchange waters due to the limited sample volumes available.

Results

Aqueous phase -

The analytical results obtained on the water samples collected during the three surveys are summarized in Figures 20 through 30, which present the mean values for each station.

The discrete values obtained for each individual sample are presented in the Appendix, Tables A-1 through A-7. Throughout this discussion, notation is based on station number, rather than river mile and distance from shore. These station numbers are defined in Figure 19 and Table 15.

Dissolved oxygen - The data resulting from the insitu measurement of dissolved oxygen is presented in the Appendix, Tables A-1 through A-3. Analysis of this data reveals that during the summer survey (August 1973) the overall dissolved oxygen level rose slightly from the head of the St. Clair River to its mouth (8.3 to 8.7). Very little variation in dissolved oxygen concentrations was observed as a function of depth, with the exception of station 1, which had a somewhat higher concentration at the surface. No dissolved oxygen levels below 6.0 mg/l were observed at any station or depth. More substantial variation in dissolved oxygen concentration as a function of depth was observed in the Detroit River during this survey. Although the dissolved oxygen concentration at the surface was 6.7 mg/l or greater at all stations, half of the stations exhibited values below 6 mg/l at depths ranging from 3 to 10 meters (10 to 34 feet). The overall average dissolved oxygen concentration was observed to drop from a value of 7.6 mg/l at the head end of the river to 7.0 mg/l at the mouth.

During the November survey, dissolved oxygen levels were generally higher than during the previous survey, undoubtedly due to the higher oxygen solubility at the lower temperature. The two very low values reported at station 1 are probably due to equipment malfunction. A greater variation of dissolved oxygen with respect to depth was observed in the St. Clair River and the head of the Detroit River. The levels were more constant with depth in all of the Detroit River other than the headwaters.

Dissolved oxygen levels of less than 6.0 mg/l were observed in the St. Clair River at stations 2 and 4 near the bottom. The Detroit River yielded only two values below 6.0 mg/l. These were recorded in 24 feet of water at stations 5 and 6. During this November survey, the net change in dissolved oxygen from the head to the mouth of the Detroit River was an increase of about 3 mg/l.

The May survey indicated very little dissolved oxygen gradient as a function of depth in either of the two rivers. Similarly, neither of the rivers exhibited dissolved oxygen concentrations below 6.0 mg/l. There was no net change in the average dissolved oxygen from the head to the mouth of the St. Clair River, while the average concentration in the Detroit River decreased from 11.6 to 10.9 mg/l between the head and the mouth.

Temperature - Virtually all stations appeared to be relatively homogeneous from surface to maximum depth with regards to temperature during all three surveys. The temperature differential between upstream and downstream stations followed different patterns in the two river systems. In the St. Clair River, the average temperature decreased 1.4°C at the time of the August survey, and increased 0.9°C at the time of the May survey, with no change being evident during the November survey. The Detroit River was observed to experience a temperature increase during all three surveys, amounting to 1.7°C in August, 0.5°C in November, and 3.1°C in May.

Specific Conductance - Specific conductance was measured insitu at each station during each of the three surveys. (Tables A-1 through A-3.)

A survey of the specific conductance data reveals a reasonably well-defined trend of increasing conductance (and hence increasing dissolved ion concentration) as the waters progress from the head of the St. Clair River, through Lake St. Clair and subsequently to the mouth of the Detroit River. The net overall effect observed in the August survey is an increase in conductance of 50 percent. Such a trend is not evident in the data from the November survey. Indeed, no net change was observed through the total system. During the May survey, the trend of increasing conductance was again evident, though the net increase through the total system amounted to only about 40 percent.

Biochemical Oxygen Demand - Analysis of the biochemical oxygen demand (BOD) data, presented in Figures 20 and Tables A-4 through A-6, indicates that the BOD load entering the St. Clair River is relatively small. Mean BOD levels at station 3 and 4 in the St. Clair River is relatively small. Mean BOD levels at station 3 and 4 in the St. Clair River are only slightly higher than the upstream stations 1 and 2. Very little change in the mean BOD is observed in the Detroit River prior to stations 10 and 11. At this point the loadings from the Rouge River and adjacent industrial and municipal outfalls are reflected in the elevated BOD at station 10. Waters on the Canadian side of the river at this milepoint are still relatively unaffected, with BOD levels essentially the same as influent waters from Lake St. Clair (stations 5-7). The elevated BOD is evident at all stations along the western shore of the river from station 10 to the point of entry into Lake Erie. At the same time, the BOD in and to the east of the shipping channels appear to remain essentially constant to the interface with Lake Erie.

Chemical Oxygen Demand - Chemical Oxygen Demand (COD) data for the aqueous phase follow much the same pattern as BOD (Figure 21 and Tables A-4 through A-6). Little difference is seen in the values from the headwater and mouth stations of the St. Clair

Figure 20. Mean biochemical oxygen demand

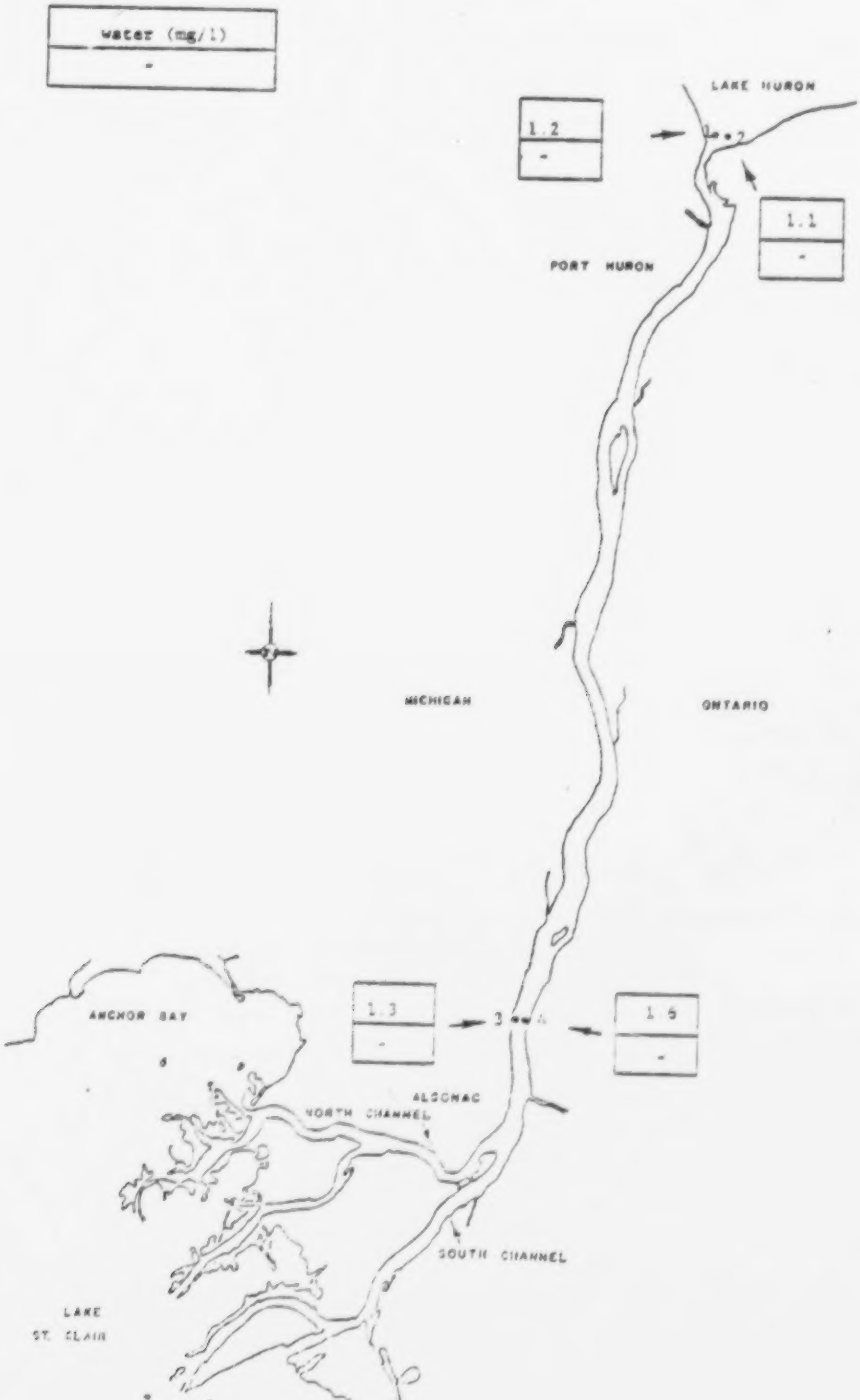

water (mg/l)
-
LAKE HURON
1.2
-
1
2
1.1
-
PORT HURON
MICHIGAN
ONTARIO
1.3
-
3
4
1.5
-
ANCHOR BAY
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 20.Mean biochemical oxygen demand (continued)

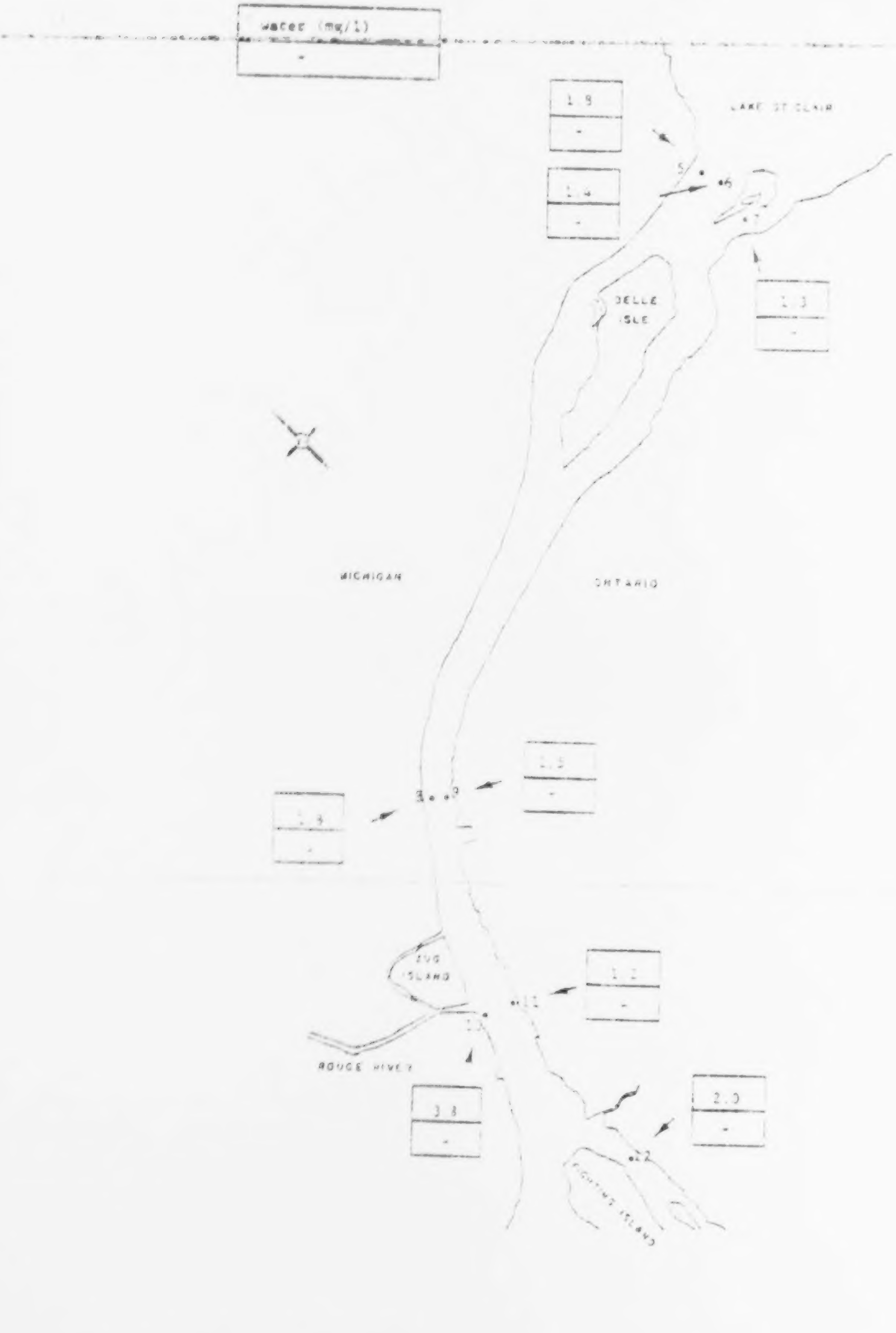

water (mg/l)
-
1.8
-
1.4
-
1.3
-
LAKE ST CLAIR
5
6
7
BELLE ISLE
MICHIGAN
ONTARIO
1.5
-
1.8
-
8
9
ZUG ISLAND
11
10
ROUGE RIVER
1.2
-
3.8
-
2.0
-
12
FIGHTING ISLAND

Figure 20.Mean biochemical oxygen demand
(continued)

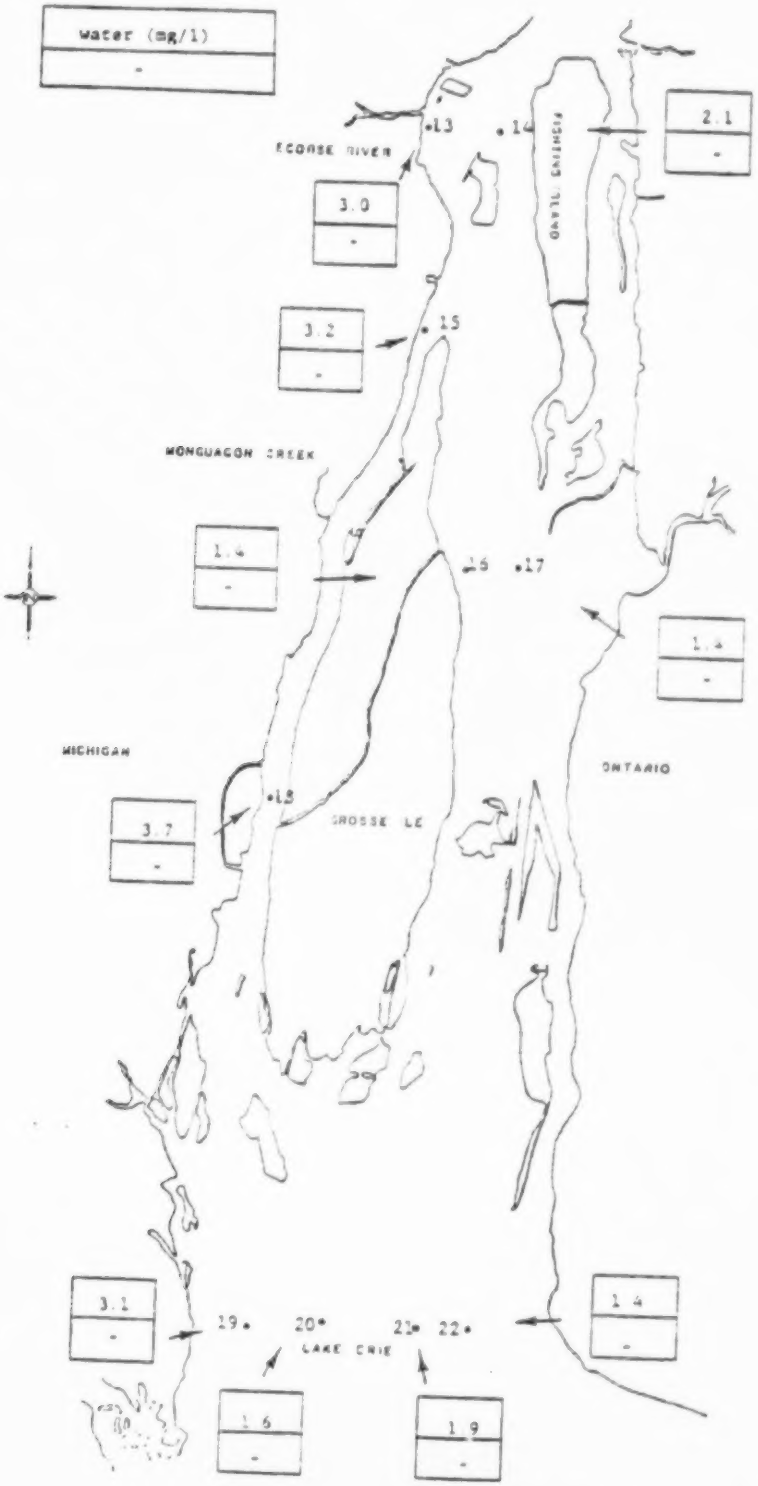

water (mg/l)
-
2.1
-
.13
.14
ECORSE RIVER
FIGHTING ISLAND
3.0
-
3.2
-
.15
MONGUAGON CREEK
1.4
-
.16
.17
1.4
-
MICHIGAN
ONTARIO
3.7
-
.18
GROSSE ILE
3.1
-
19.
20.
21.
22.
LAKE ERIE
1.4
-
1.6
-
1.9
-

Figure 21. Mean chemical oxygen demand

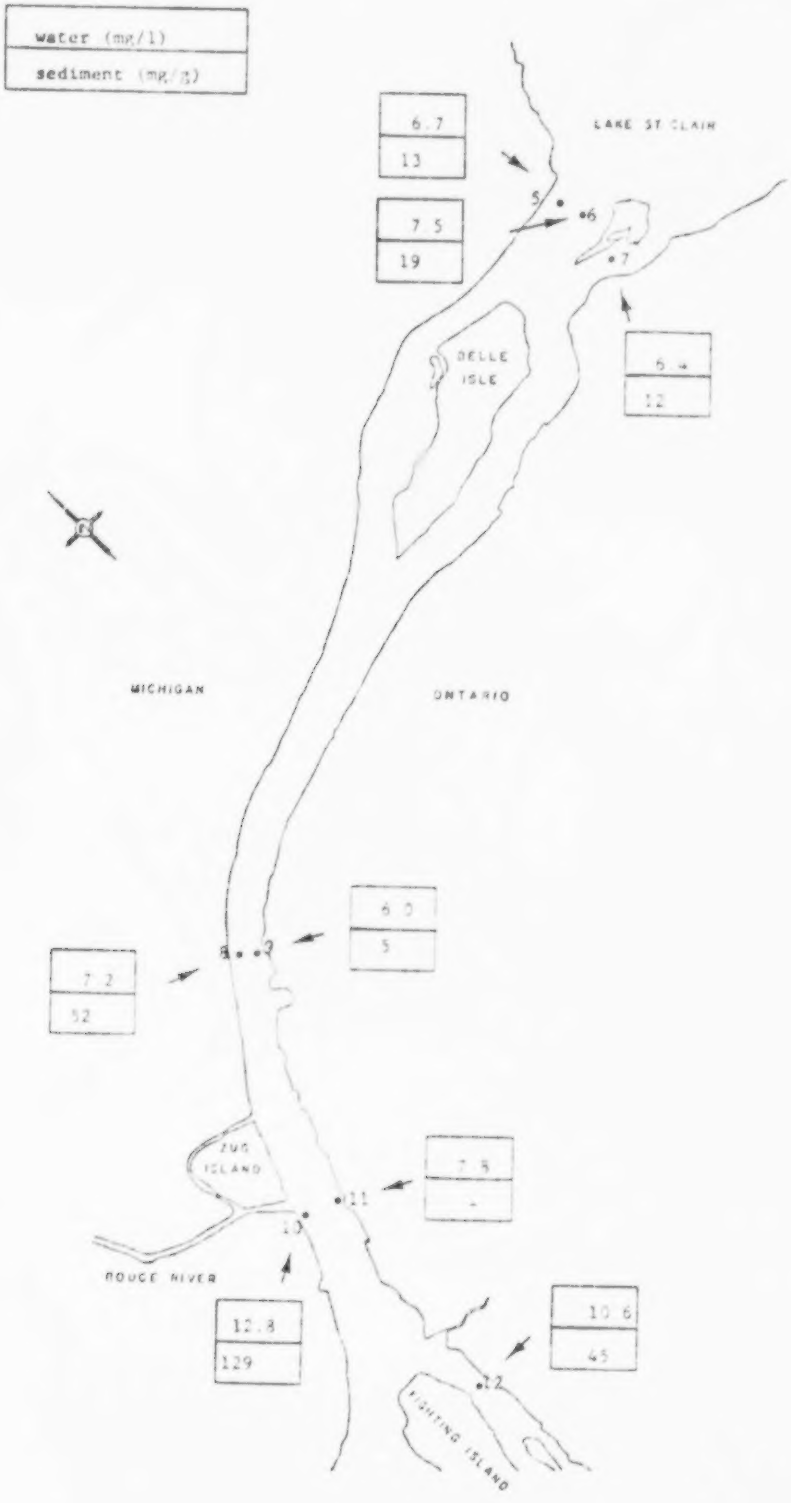

water (mg/l)
sediment (mg/g)
LAKE ST CLAIR
6.7
13
7.5
19
5
6
7
6.4
12
BELLE ISLE
MICHIGAN
ONTARIO
6.0
5
7.2
52
8
9
ZUG ISLAND
7.8
-
11
10
ROUGE RIVER
12.8
129
10.6
45
12
FIGHTING ISLAND

Figure 21 Mean chemical oxygen demand
(continued)

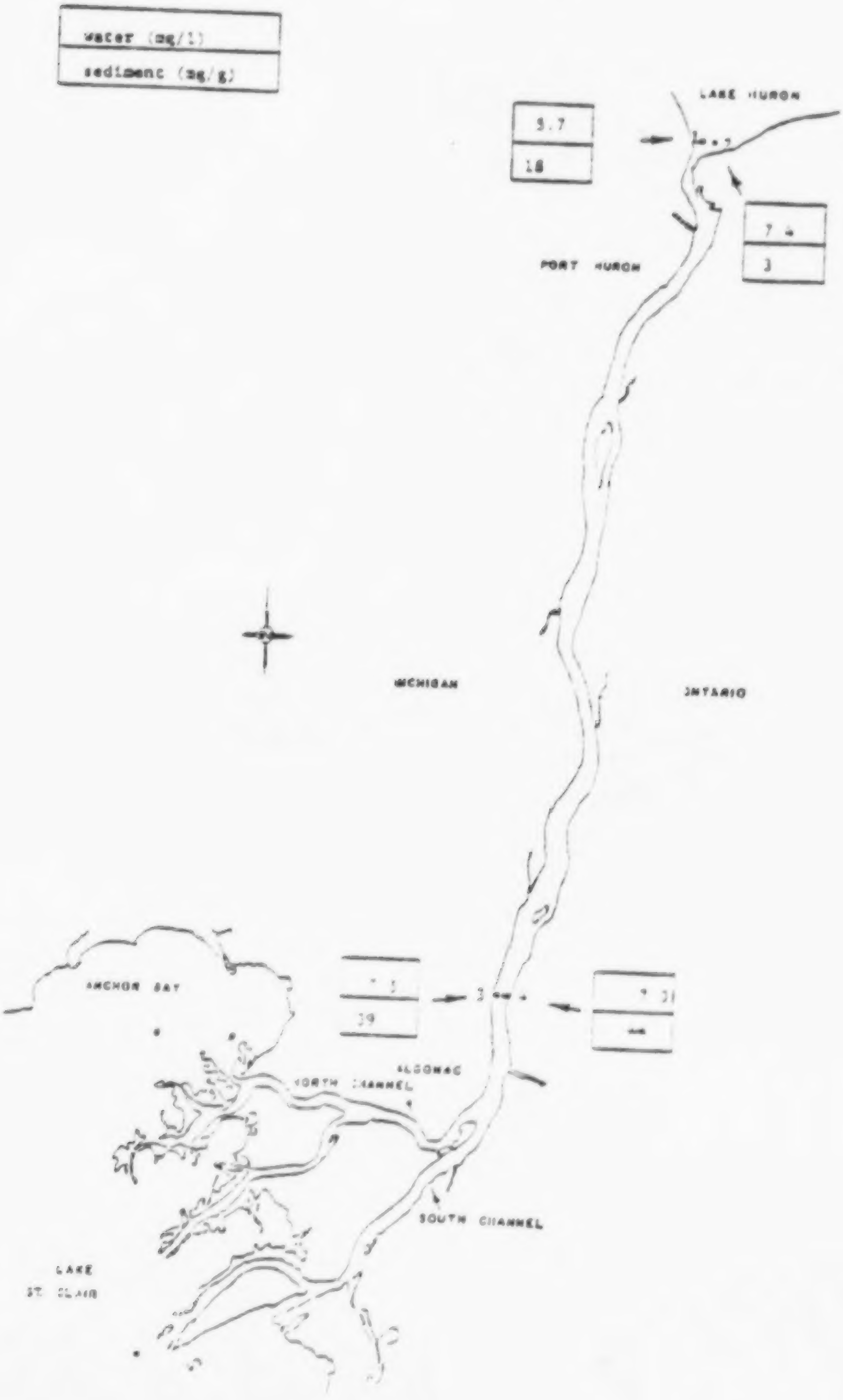
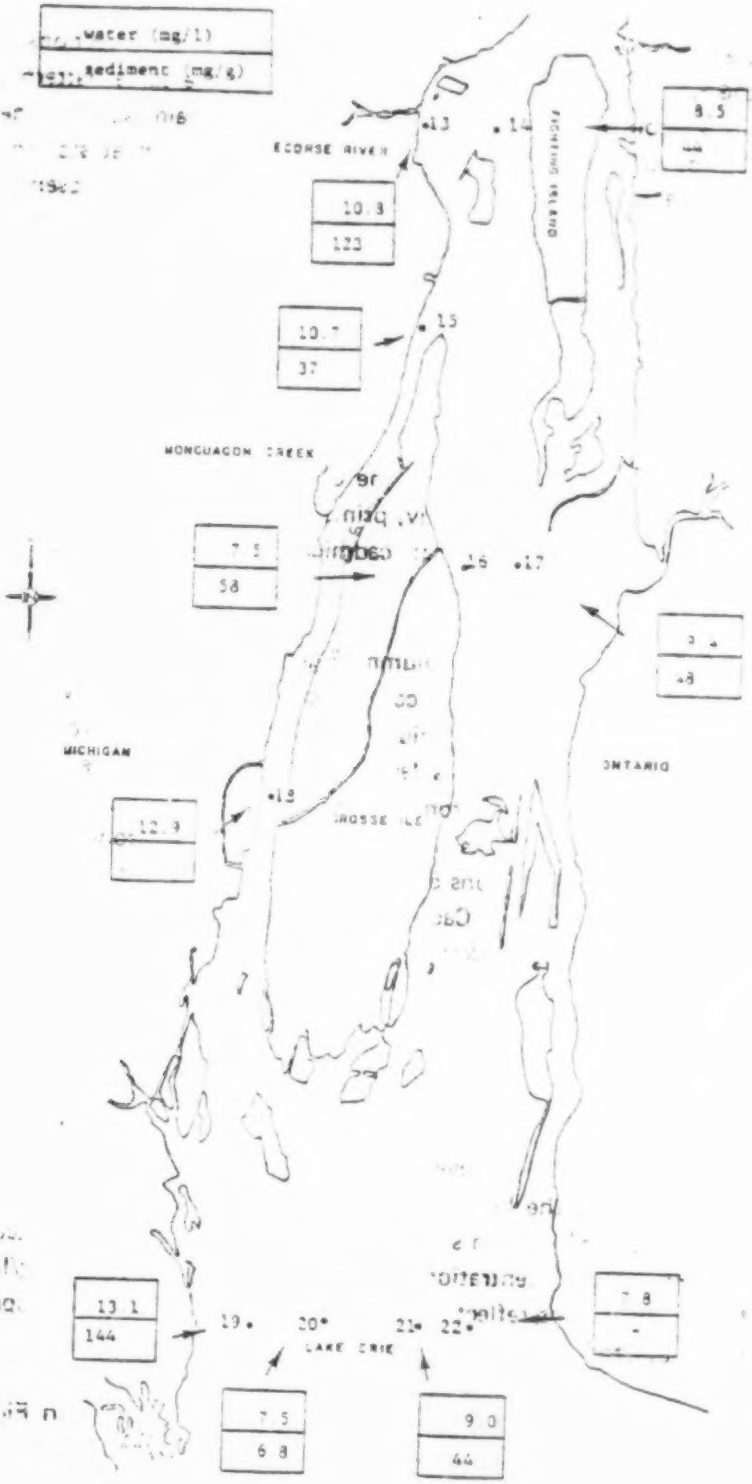

water (mg/l)
sediment (mg/g)
LAKE HURON
5.7
18
7.4
3
PORT HURON
MICHIGAN
ONTARIO
ANCHOR BAY
7.1
39
3
7.3
—
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 21 Mean chemical oxygen demand
(continued)


water (mg/l)
sediment (mg/g)
ECORSE RIVER
FIGHTING ISLAND
13
14
8.5
–
10.8
123
10.7
37
15
MONGUAGON CREEK
7.5
58
16
17
3.4
48
MICHIGAN
ONTARIO
18
GROSSE ILE
12.9
13.1
144
19
20
21
22
LAKE ERIE
7.5
68
9.0
44
7.8
-

River. No appreciable differences are observed in the Detroit River until stations 10 and 11. At station 10 the COD approximately doubles - following the same pattern as the BOD at that station. By contrast, COD values for station 11 remain close to the level observed at stations 5, 6, and 7. An evident increase in COD is seen at station 12 in the Canadian waters, where only a very slight increase in mean BOD was observed. As in the case with BOD, elevated COD values are noted at all stations along the United States shore of the river. Canadian waters below station 12 are only slightly higher in COD than the influent water from Lake St. Clair.

Trace metals - A major consideration in the chemical field monitoring program was to provide information on the concentrations of trace metals in the water column. Since little historical data was available, the information generated during this phase of the study would serve as a preliminary step in diagnosing the condition of the rivers in terms of trace metals. Nine metals were chosen for study, primarily on the availability of relevant toxicity information. The metals included were: cadmium, chromium, copper, iron, lead, manganese, mercury, nickel and zinc.

Mean cadmium concentrations in the water column (Figure 22) do not vary appreciably from the head of the St. Clair River to the confluence of the Rouge River with the Detroit River. At station 10 the mean cadmium concentration rises approximately 67 percent over levels observed upstream. This level is maintained downstream along the United States shoreline and into the Trenton Channel. At station 18, below most of the industrial outfalls on the United States shore, the mean cadmium concentration rises to three times the levels observed at stations 5, 6, and 7. This level falls off only slightly by the time the water reaches station 19. Cadmium levels in the remainder of the Detroit River remain essentially the same as background levels until stations 21 and 22 where mean concentrations are approximately 33 percent higher than influent water from Lake St. Clair.

Chromium results are summarized in Figure 23. Unlike cadmium, a variation in aqueous chromium levels does occur in the St. Clair River stations and the upriver stations of the Detroit River (stations 5-9). Mean levels range from 2.7 to 6.1 µg/l, with station 1 being the lowest and station 3 the highest. The levels above station 10 in the Detroit River vary from 4.3 to 12.1 µg/l. From station 10 downstream along the United States shore to Lake Erie, chromium concentrations remain high (10.8 to 17.1 µg/l). The remainder of the downriver stations reflect concentrations which do not vary appreciably from background levels at stations 5, 6, and 7.

Mean copper concentrations observed in the water column are presented in Figure 24.

Figure 22. Mean cadmium concentration

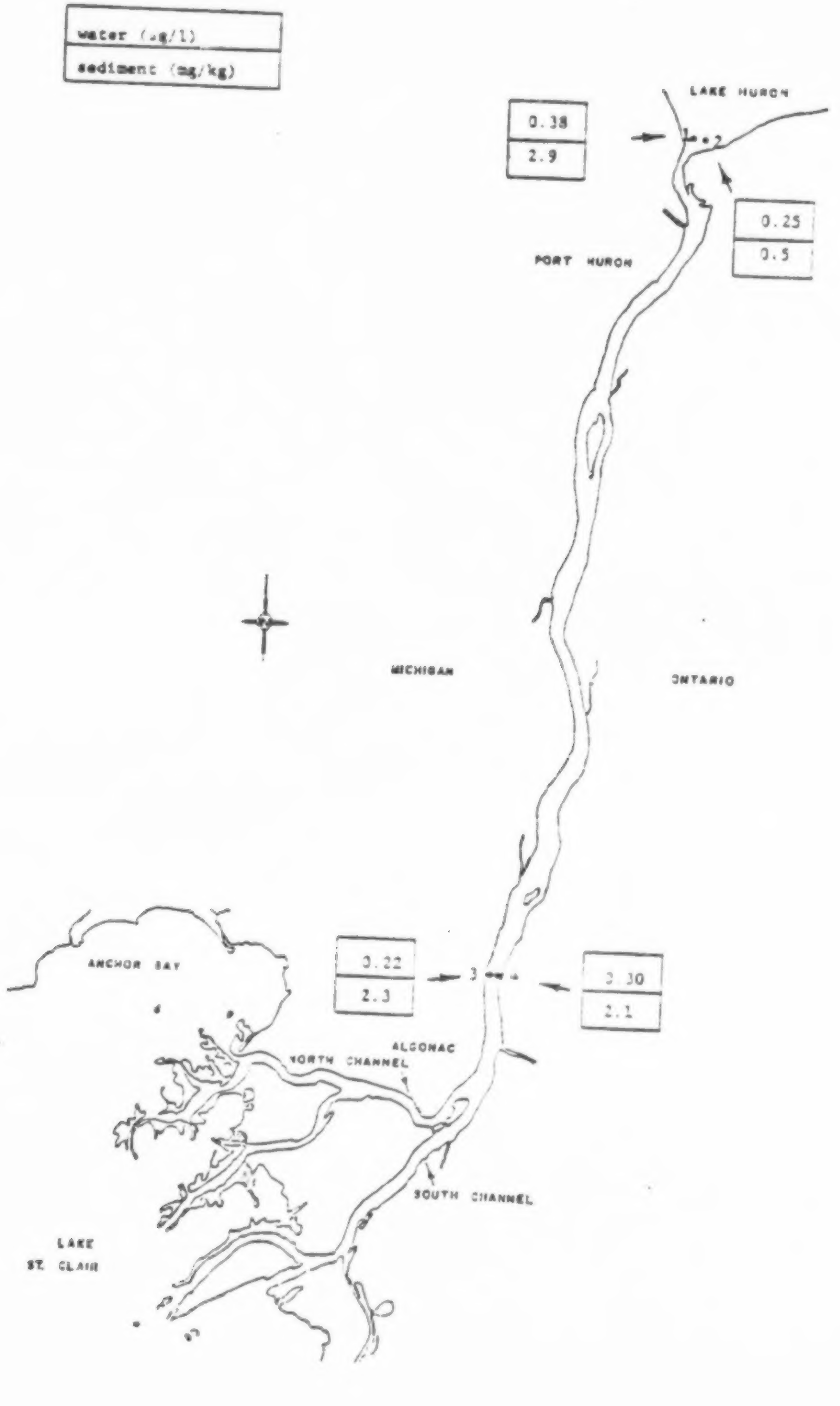

water (µg/l)
sediment (mg/kg)
LAKE HURON
1
2
0.38
2.9
0.25
0.5
PORT HURON
MICHIGAN
ONTARIO
ANCHOR BAY
3
4
0.22
2.3
0.30
2.1
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 22. Mean cadmium concentration (continued)

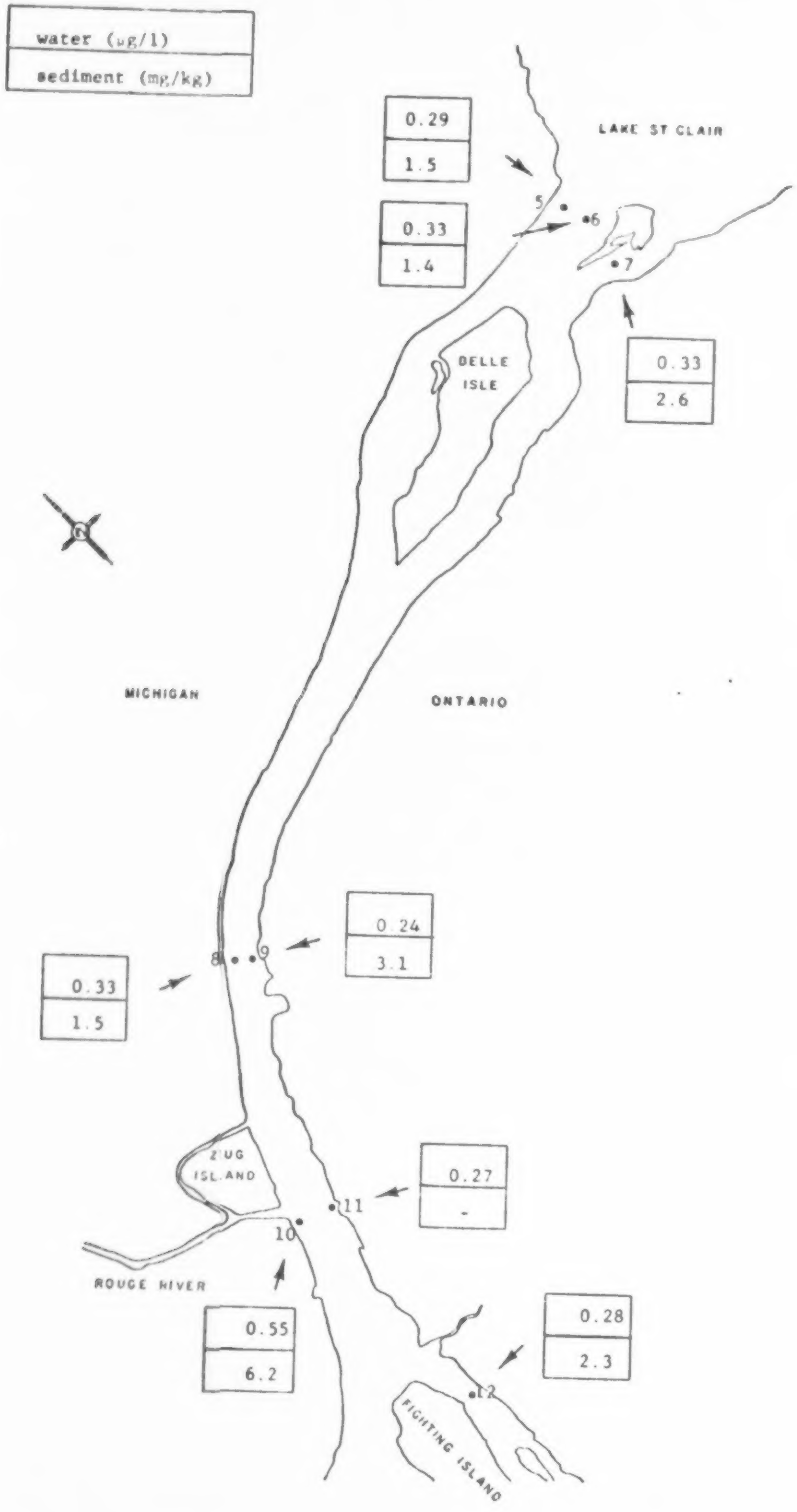

water (µg/l)
sediment (mg/kg)
LAKE ST CLAIR
0.29
1.5
0.33
1.4
5
6
7
0.33
2.6
BELLE ISLE
MICHIGAN
ONTARIO
0.24
3.1
8
9
0.33
1.5
ZUG ISLAND
0.27
-
11
10
ROUGE RIVER
0.55
6.2
0.28
2.3
12
FIGHTING ISLAND

Figure 22. Mean cadmium concentration (continued)

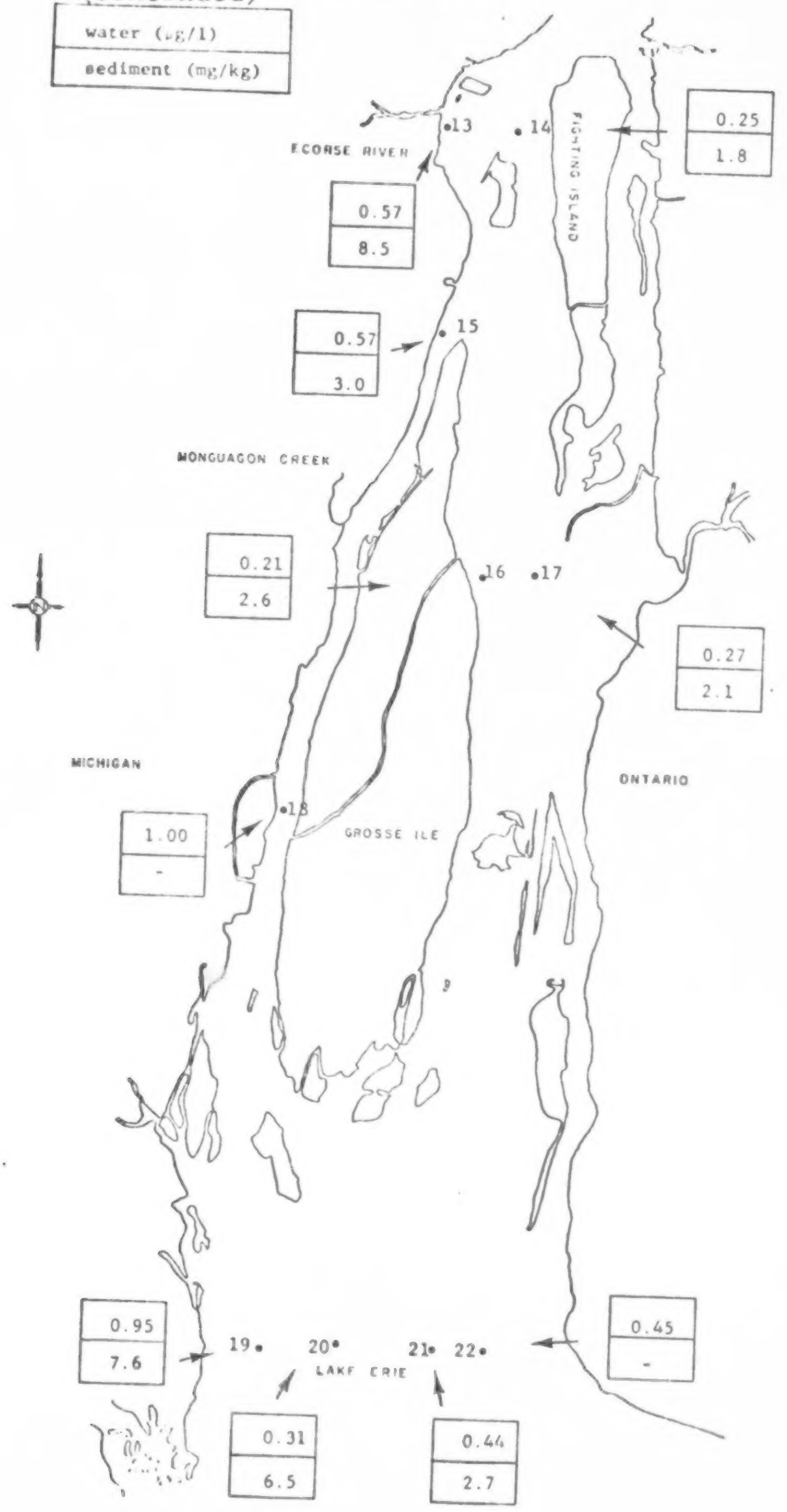

water (µg/l)
sediment (mg/kg)
ECORSE RIVER
13
14
FIGHTING ISLAND
0.25
1.8
0.57
8.5
0.57
3.0
15
MONGUAGON CREEK
0.21
2.6
16
17
0.27
2.1
N
MICHIGAN
ONTARIO
1.00
-
18
GROSSE ILE
0.95
7.6
19
20
21
22
LAKE ERIE
0.45
-
0.31
6.5
0.44
2.7

Figure 23.Mean chromium concentration

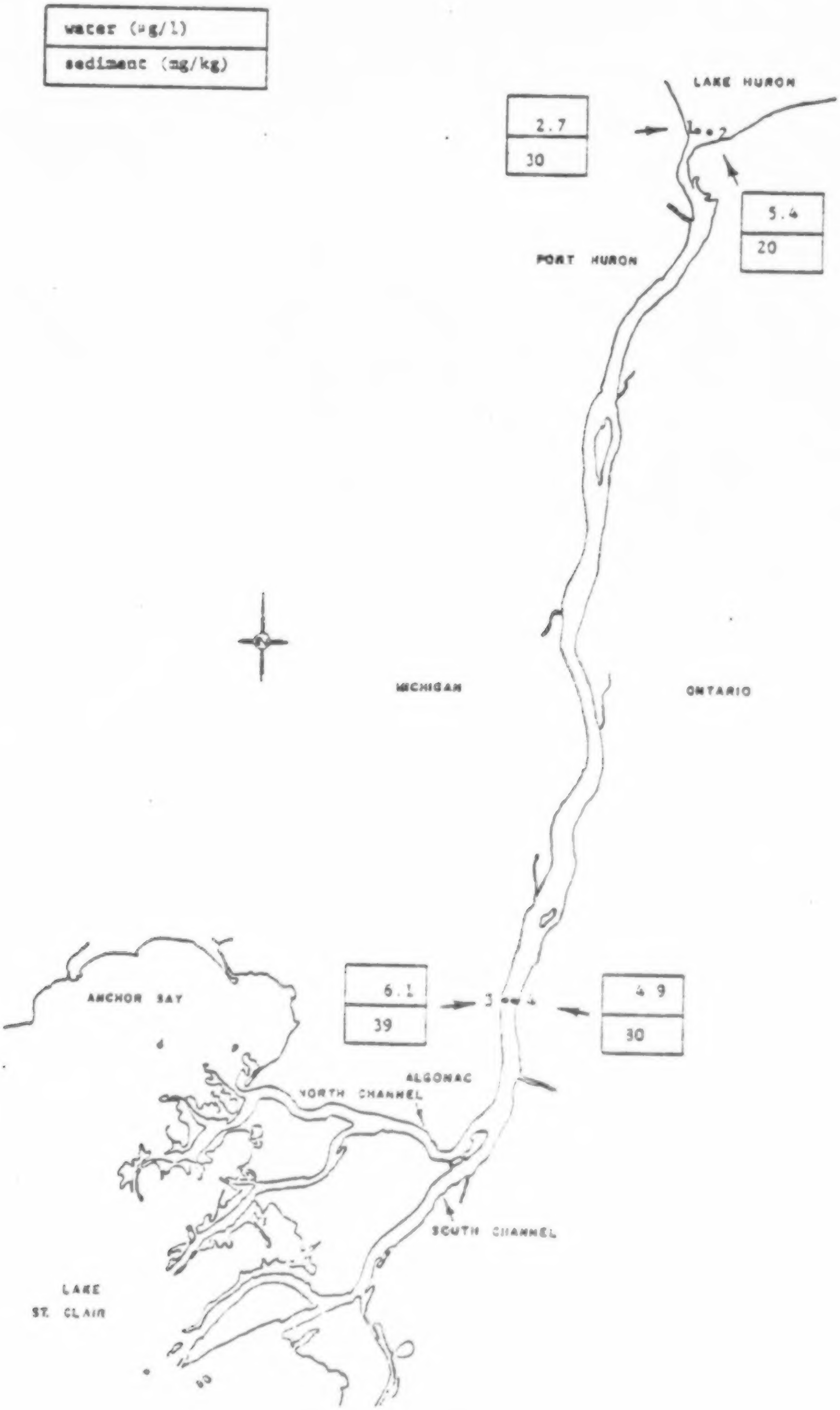

water (µg/l)
sediment (mg/kg)
LAKE HURON
2.7
30
1
2
5.4
20
PORT HURON
MICHIGAN
ONTARIO
6.1
39
3
4
4.9
30
ANCHOR BAY
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 23 Mean chromium concentration (continued)

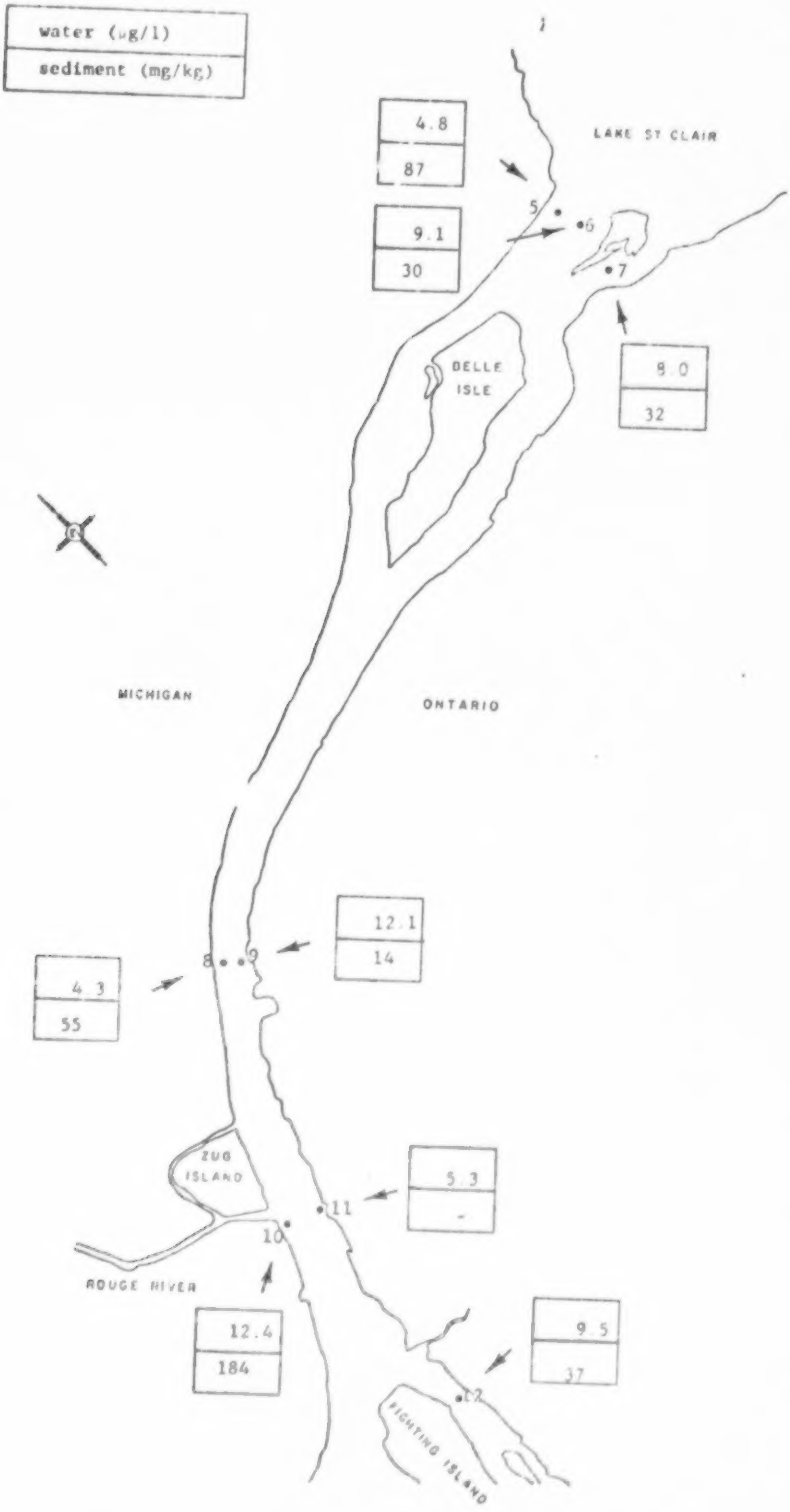
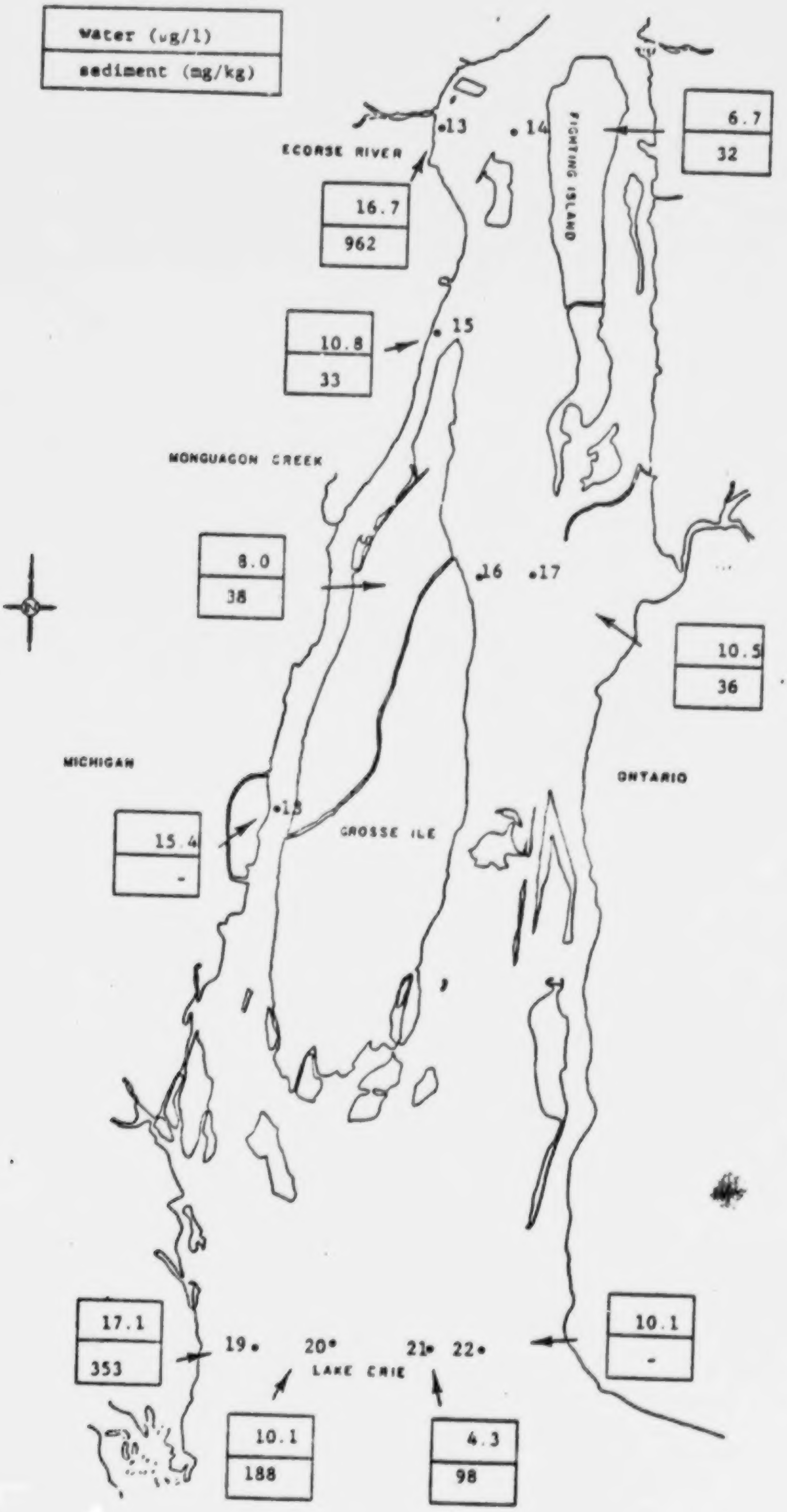

water (µg/l)
sediment (mg/kg)
LAKE ST CLAIR
4.8
87
5
6
9.1
30
7
8.0
32
BELLE ISLE
MICHIGAN
ONTARIO
8
9
4.3
55
12.1
14
ZUG ISLAND
ROUGE RIVER
10
11
12.4
184
5.3
-
12
9.5
37
FIGHTING ISLAND

Figure 23.Mean chromium concentration
(continued)



water (μg/l)
sediment (mg/kg)
ECORSE RIVER
FIGHTING ISLAND
•13
•14
6.7
32
16.7
962
•15
10.8
33
MONGUAGON CREEK
8.0
38
•16
•17
10.5
36
MICHIGAN
ONTARIO
•18
GROSSE ILE
15.4
-
17.1
353
19•
20•
21•
22•
LAKE ERIE
10.1
-
10.1
188
4.3
98

Figure 24. Mean copper concentration

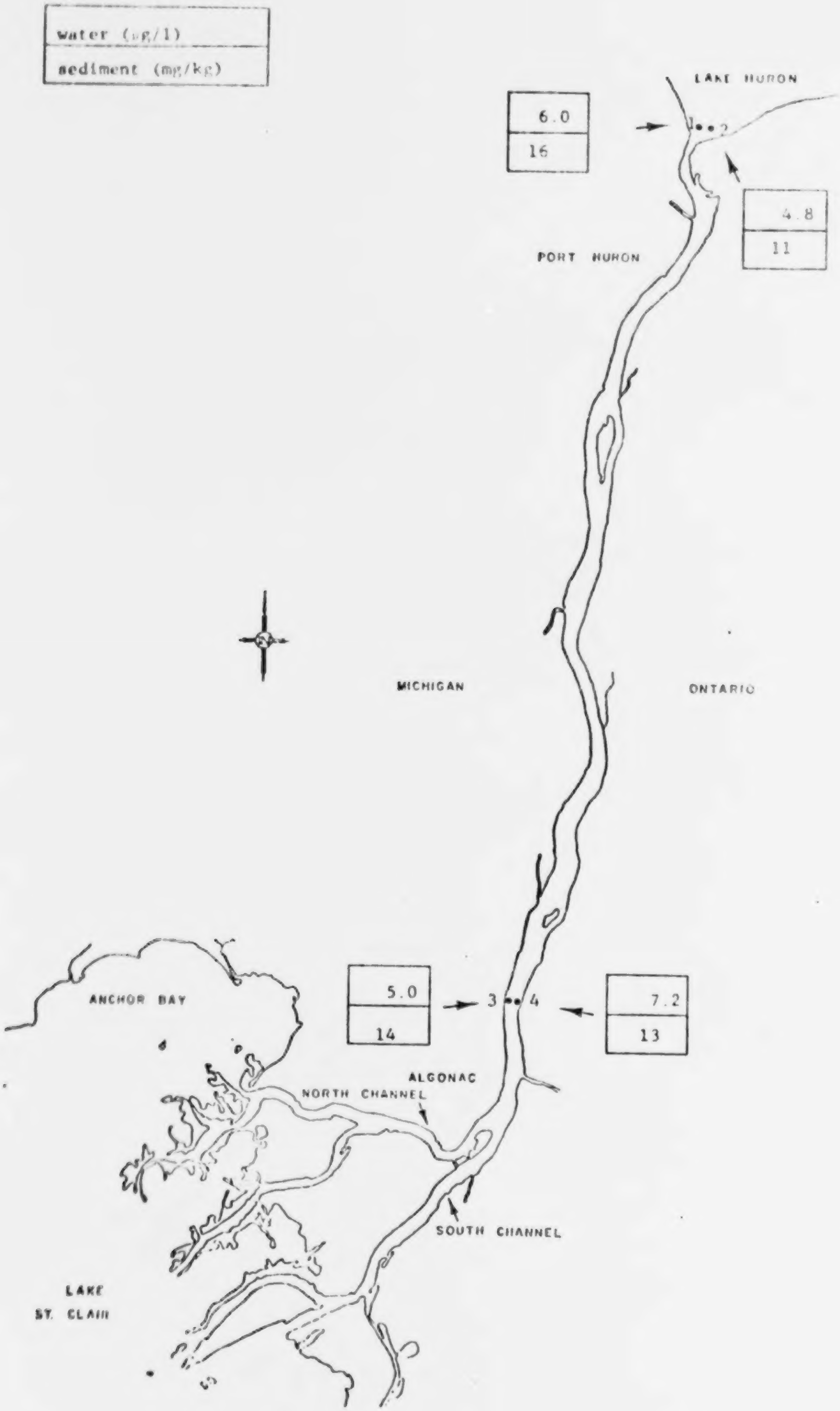

water (µg/l)
sediment (mg/kg)
LAKE HURON
6.0
16
1
2
4.8
11
PORT HURON
MICHIGAN
ONTARIO
ANCHOR BAY
5.0
14
3
4
7.2
13
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 24. Mean copper concentration
(continued)

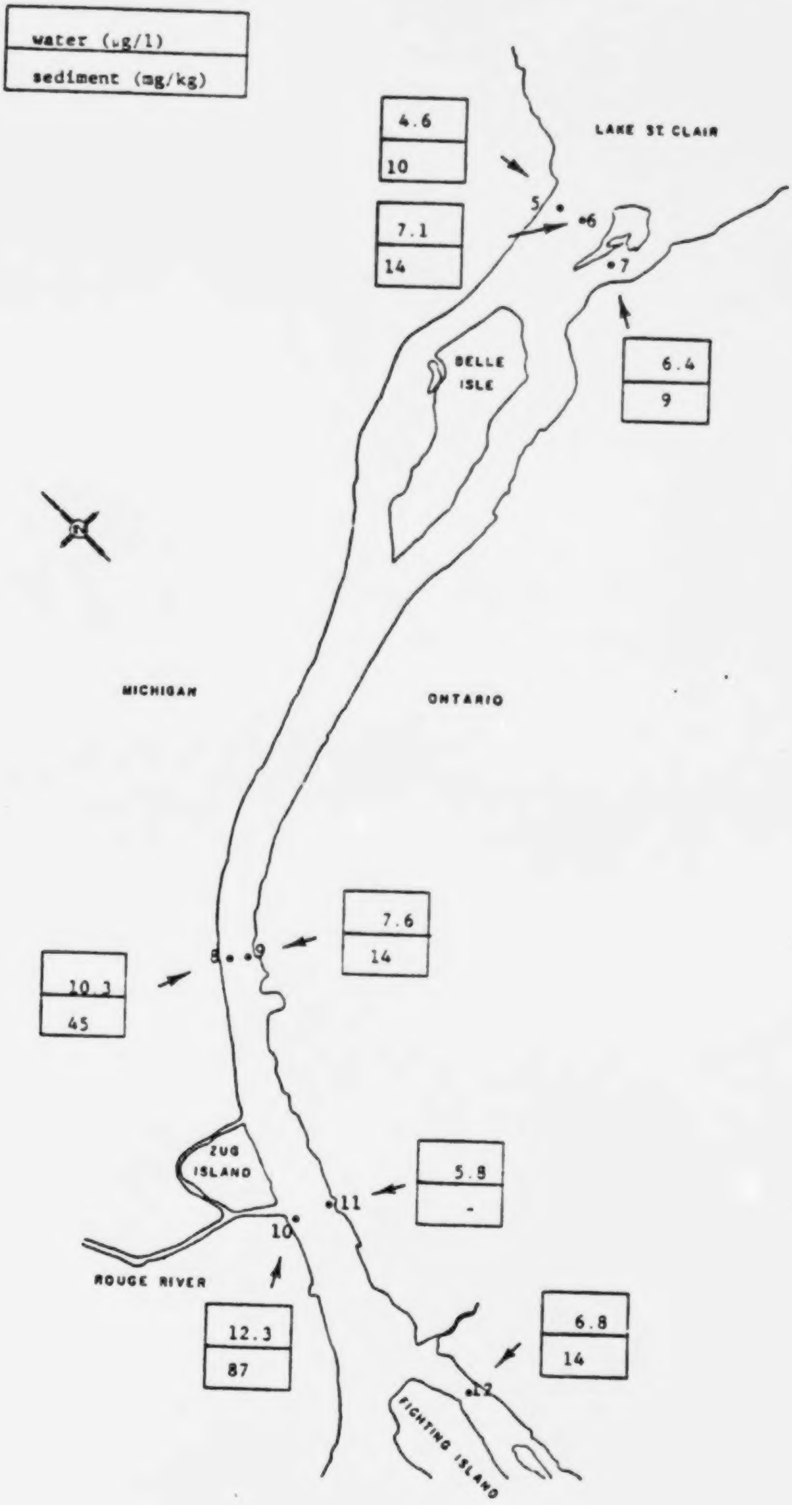
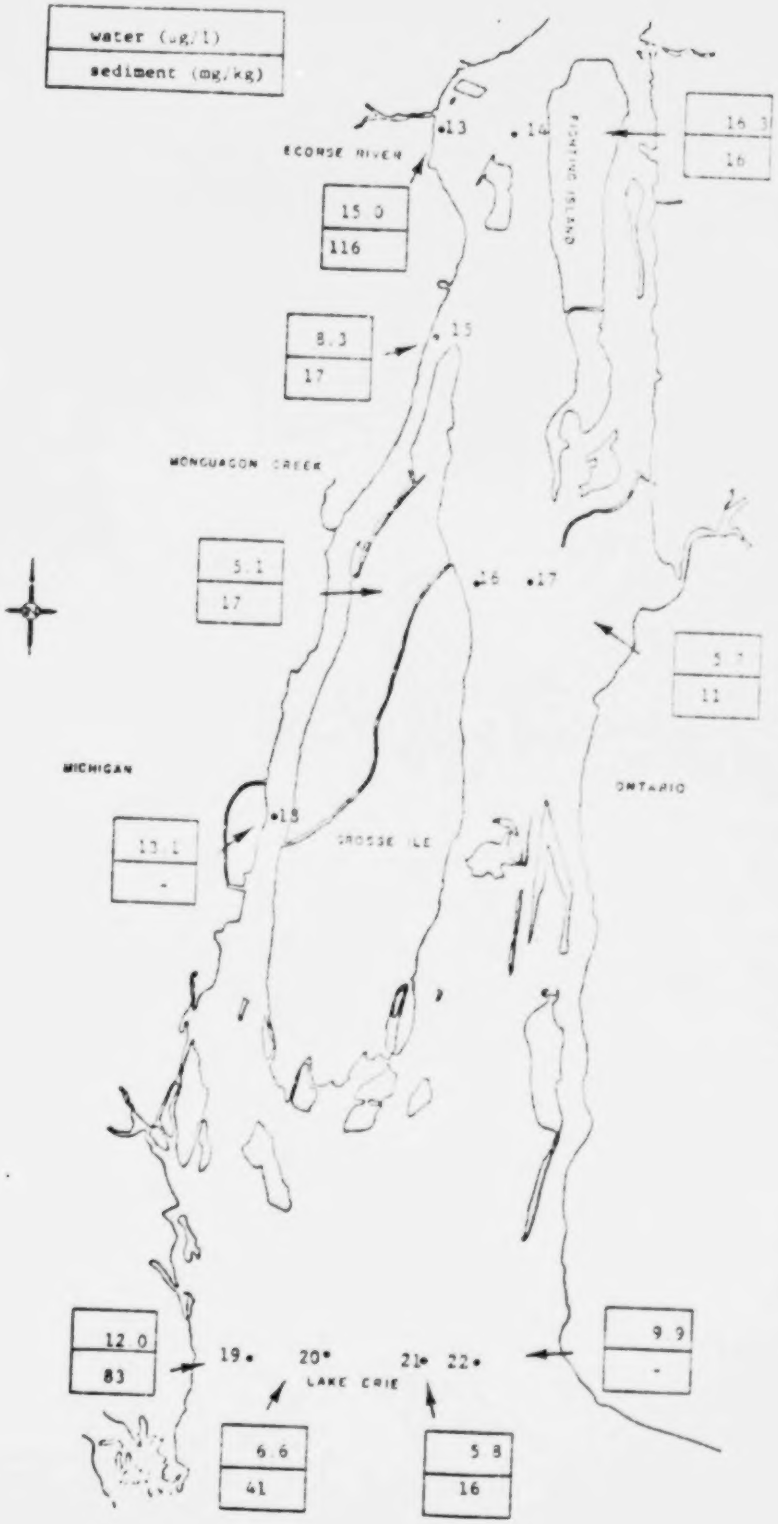

water (µg/l)
sediment (mg/kg)
4.6
10
LAKE ST CLAIR
5
6
7.1
14
7
6.4
9
BELLE ISLE
MICHIGAN
ONTARIO
7.6
14
8
9
10.3
45
ZUG ISLAND
5.8
-
11
10
ROUGE RIVER
12.3
87
6.8
14
12
FIGHTING ISLAND

Figure 24. Mean copper concentration (continued)


water (ug/l)
sediment (mg/kg)
ECORSE RIVER
FIGHTING ISLAND
MONGUAGON CREEK
MICHIGAN
ONTARIO
GROSSE ILE
LAKE ERIE
13
14
15
16
17
18
19
20
21
22
16.3
16
15.0
116
8.3
17
5.1
17
5.7
11
13.1
-
12.0
83
6.6
41
5.8
16
9.9
-

Differences in the mean concentrations in the St. Clair River indicate slightly higher levels of this metal at Stations 1 and 4. Waters entering the Detroit River from Lake St. Clair contain between 4.6 and 7.1 µg/l of total copper. A substantial enrichment is seen along the United States shoreline as early as station 8. The concentrations rise even higher at stations 10 and 13 (12.3 and 15.0 µg/l respectively), and remain elevated along the western shore until the waters enter Lake Erie at station 19. Unlike heavy metals already reviewed, mean copper levels are elevated at the mid-river station 14. (This level is due primarily to a very high level observed during the May survey.) Along the Canadian shoreline, no appreciable change is seen in copper concentration from the influent levels of Lake St. Clair until station 22 (Lake Erie interface).

Lead levels in the St. Clair River were observed to remain essentially constant from the headwater to the mouth (Figure 25) Mean concentrations in the water column remain around 2 µg/l. Influent water to the Detroit River are also of this concentration. Elevated levels are observed on both sides of the river as early as stations 8 and 9, although contamination along the United States shore is by far more evident. Waters at station 10 are approximately three times the background concentration, while the waters downstream on the United States side reach five times the background level. The evidence of the lead loadings is notable at stations 19 and 20. The Canadian waters do undergo some enrichment in lead as they move downstream, however the mean concentrations observed in this area never equal the corresponding values in waters along the western shore.

Data on aqueous mercury levels were collected during the November and May surveys only. This information is summarized in Figure 26 and presented in Tables A-5 and A-6. Mean mercury concentrations in the St. Clair River range between 1.3 and 4.6 µg/l, with the upstream stations averaging approximately twice the level of the downstream stations. Influent waters to the Detroit River show a two-fold increase in this heavy metal over stations 3 and 4 in the lower St. Clair River apparently the result of activity in the Lake St. Clair basin. No further enrichment is seen throughout the entire length of the Detroit River, with the notable exception of station 12. At this point, total mercury in the water column averages 6.4 µg/l. It should be noted that a rather substantial difference was observed between aqueous mercury levels recorded during the November survey and the May survey with substantially higher levels observed in November. In general, observed values were higher than EPA recommended levels[8] .

Nickel concentrations in the aqueous phase was monitored during all three field surveys. Mean concentrations are presented in Figure 27. A review of the mean values indicates

Figure 25. Mean lead concentrations

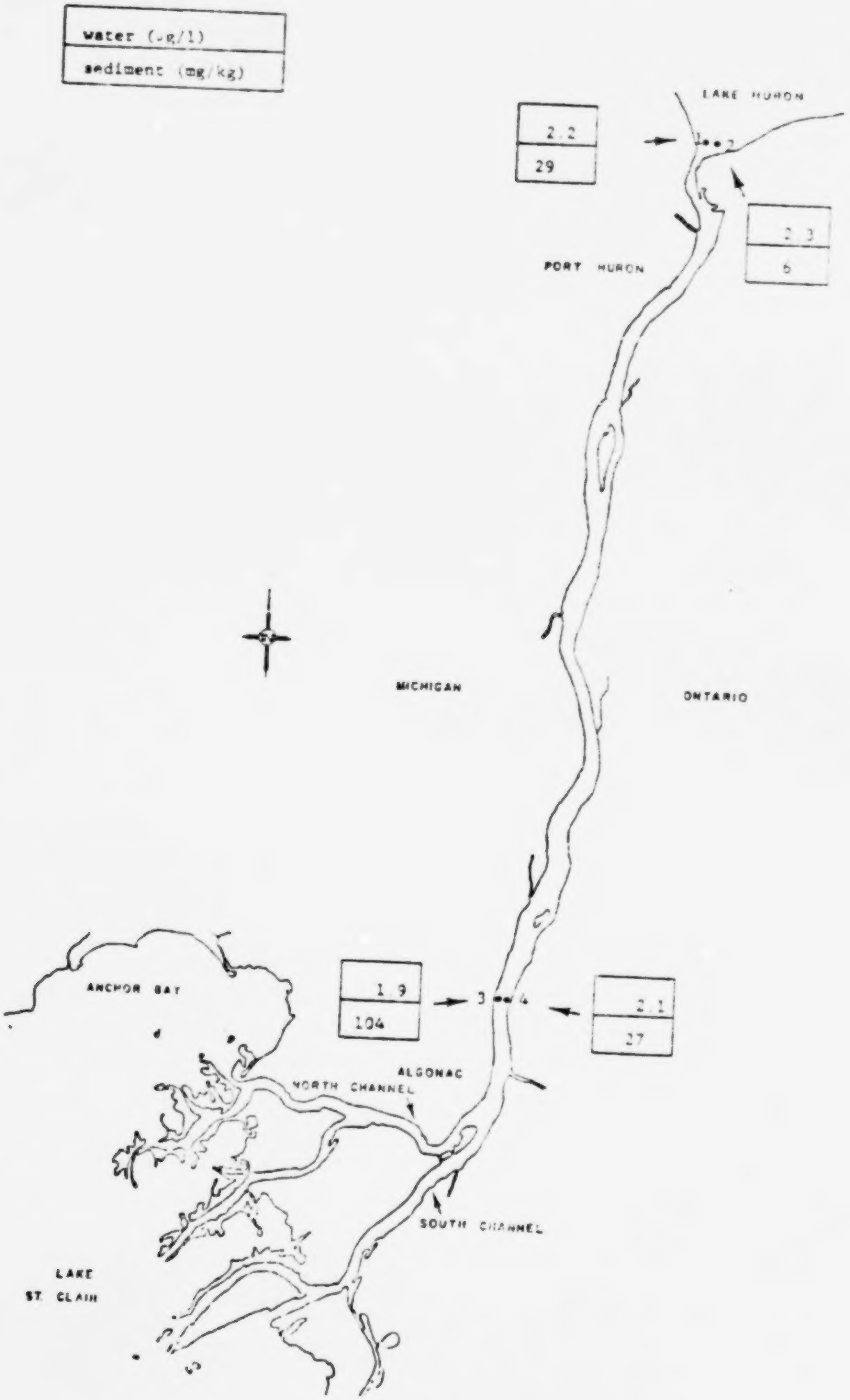

water (µg/l)
sediment (mg/kg)
LAKE HURON
2.2
29
1
2
2.3
6
PORT HURON
MICHIGAN
ONTARIO
ANCHOR BAY
1.9
104
3
4
2.1
27
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 25.Mean lead concentration (continued)

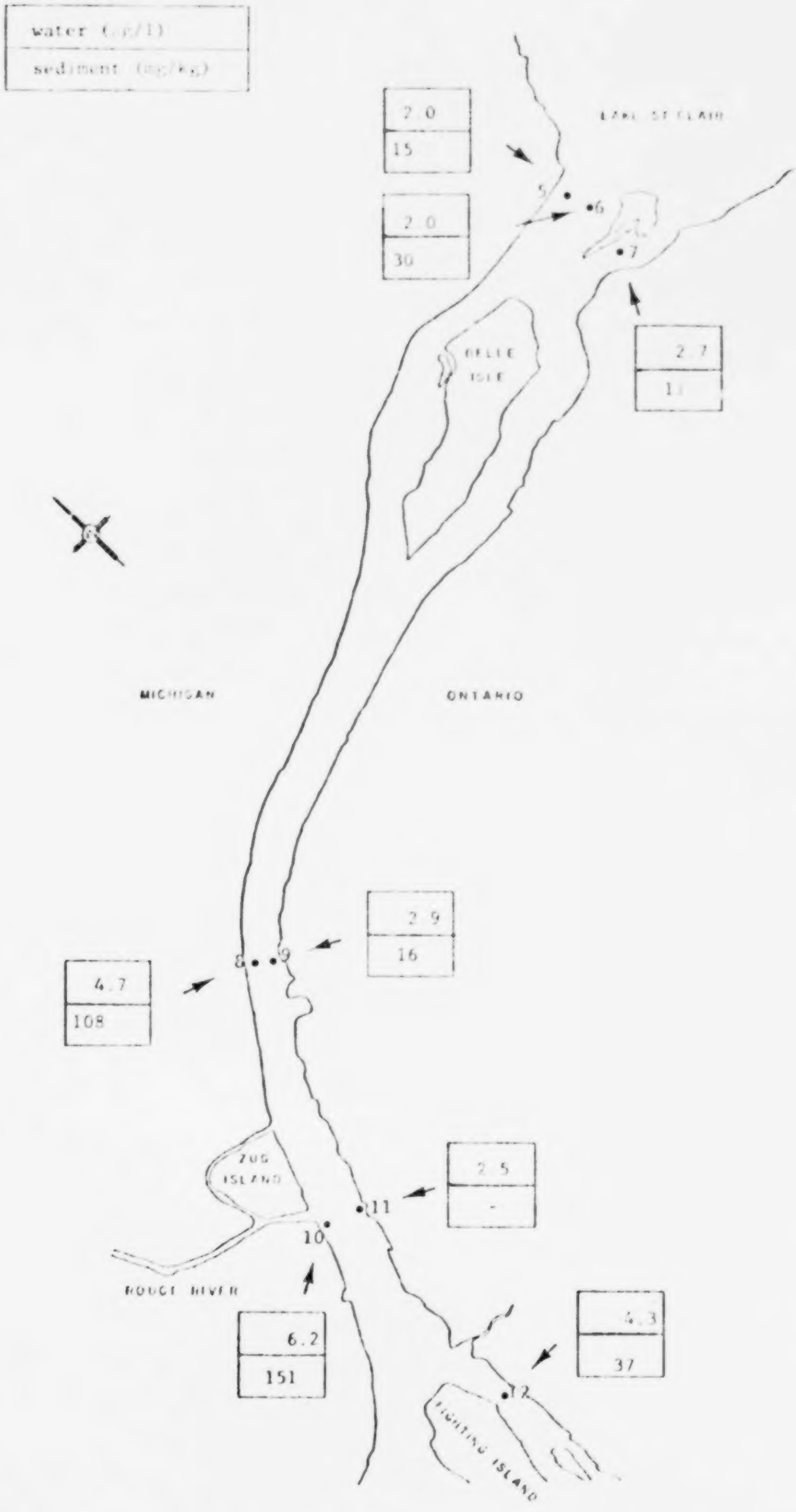
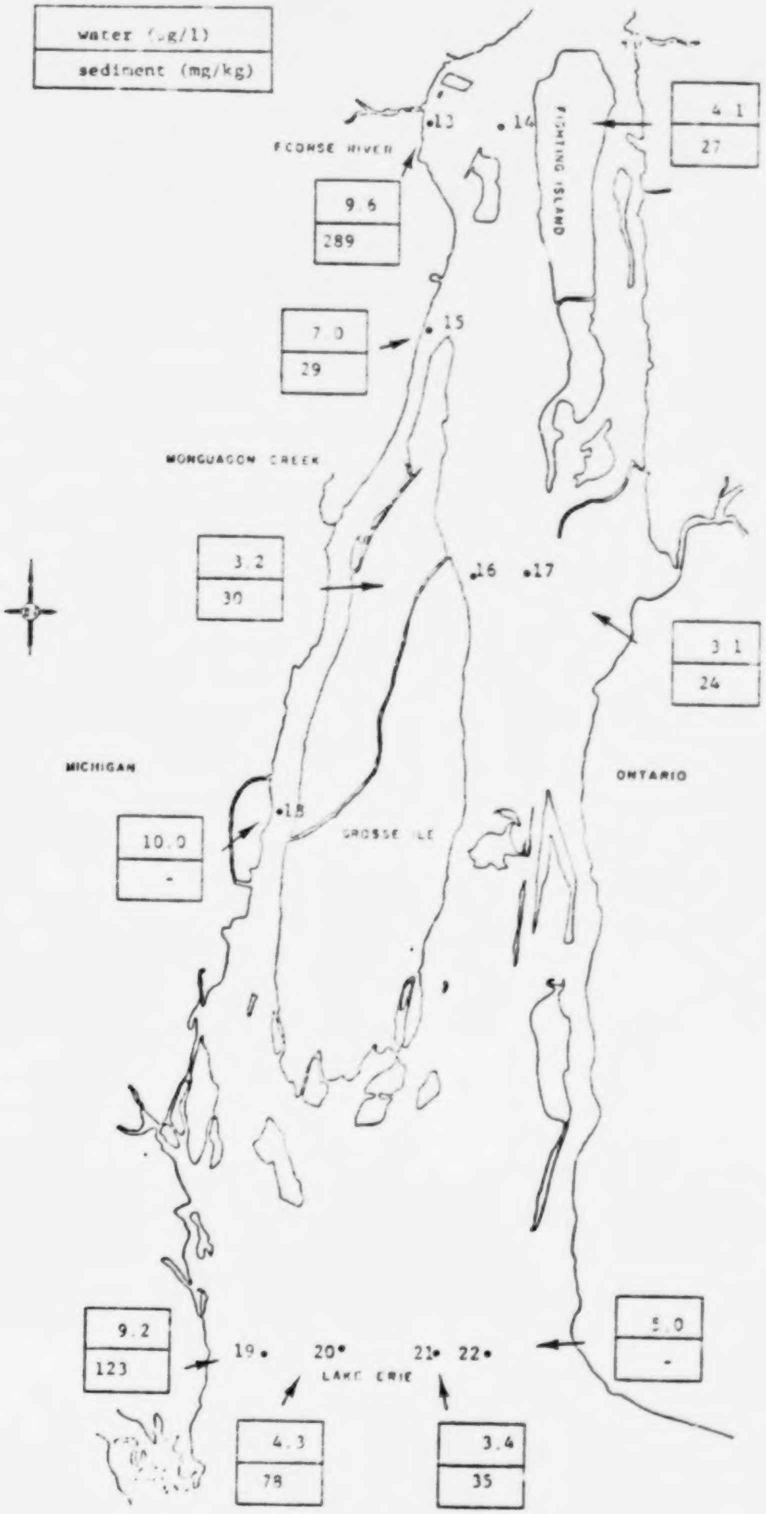
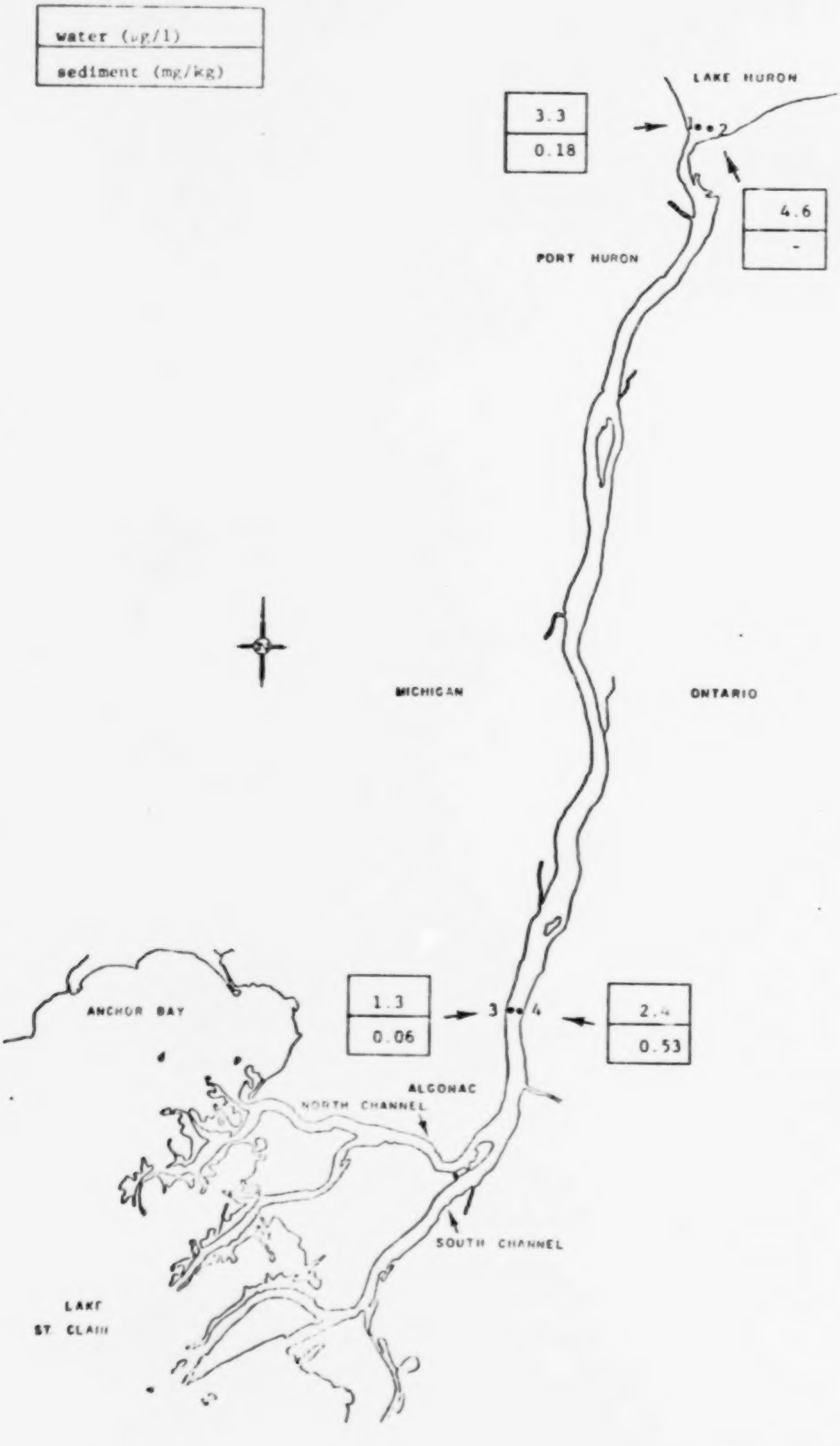

water (µg/l)
sediment (mg/kg)
LAKE ST CLAIR
2.0
15
5
6
2.0
30
7
2.7
11
BELLE ISLE
MICHIGAN
ONTARIO
2.9
16
8
9
4.7
108
ZUG ISLAND
2.5
-
11
10
ROUGE RIVER
6.2
151
4.3
37
12
FIGHTING ISLAND

Figure 25. Mean lead concentration (continued)



water (µg/l)
sediment (mg/kg)
ECORSE RIVER
•13
•14
FIGHTING ISLAND
4.1
27
9.6
289
•15
7.0
29
MONGUAGON CREEK
•16
•17
3.2
30
3.1
24
MICHIGAN
ONTARIO
•18
GROSSE ILE
10.0
-
19•
20•
21•
22•
LAKE ERIE
9.2
123
5.0
-
4.3
78
3.4
35

Figure 26. Mean mercury concentration



water (µg/l)
sediment (mg/kg)
LAKE HURON
3.3
0.18
1
2
4.6
-
PORT HURON
MICHIGAN
ONTARIO
ANCHOR BAY
1.3
0.06
3
4
2.4
0.53
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE ST. CLAIR

Figure 26 Mean mercury concentration (continued)

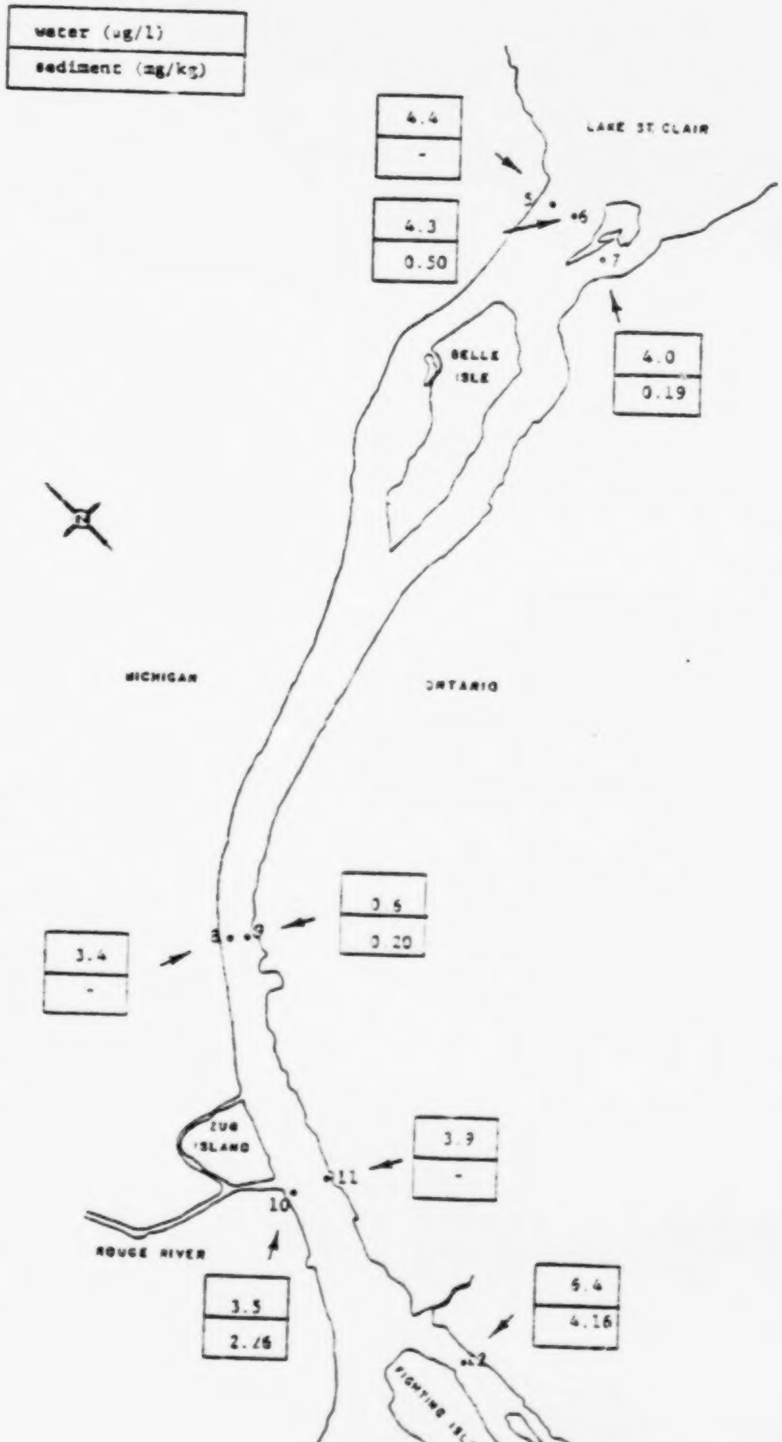
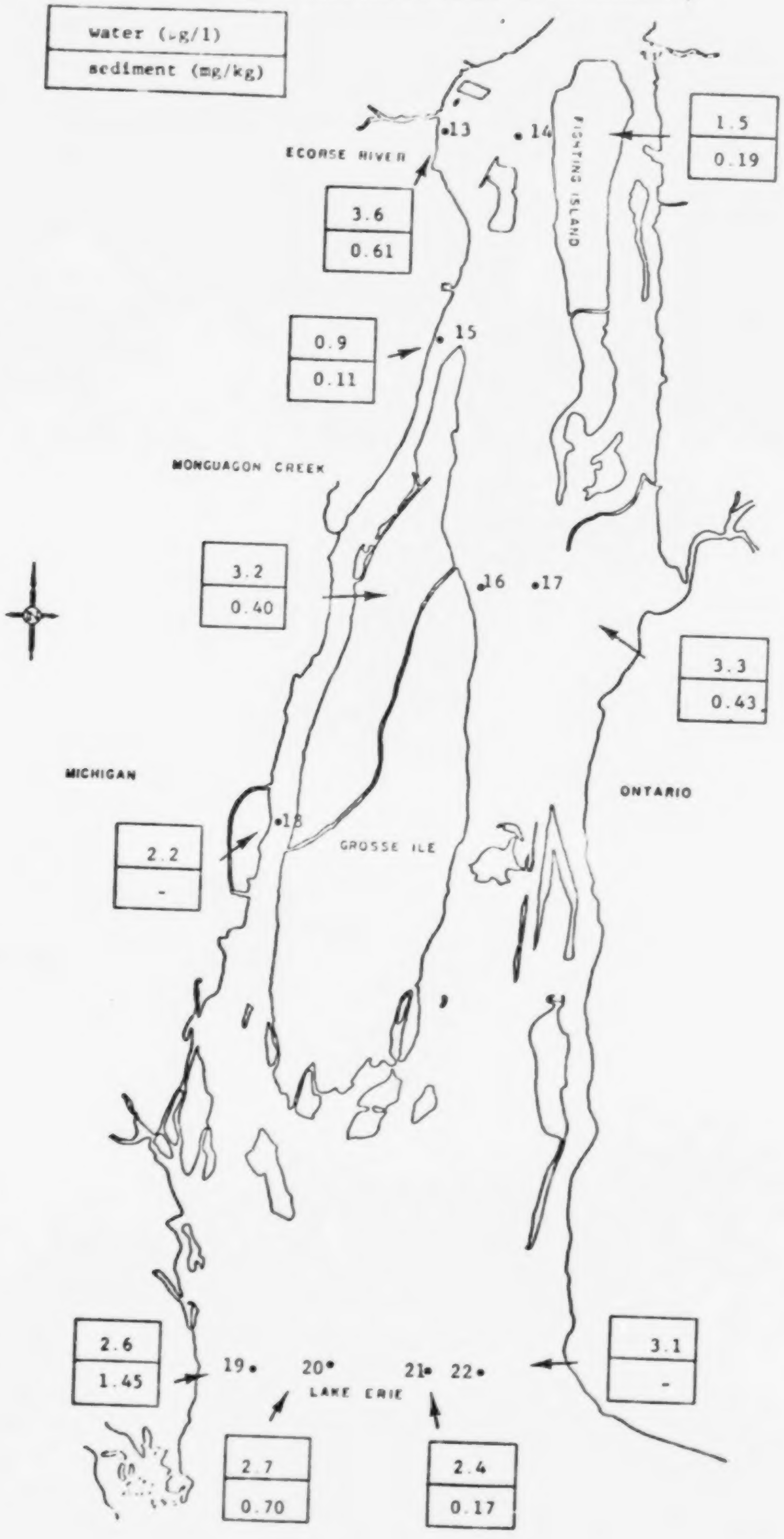

water (µg/l)
sediment (mg/kg)
LAKE ST CLAIR
4.4
-
4.3
0.50
5
6
7
4.0
0.19
BELLE ISLE
MICHIGAN
ONTARIO
8
9
3.4
-
3.5
0.20
ZUG ISLAND
ROUGE RIVER
10
11
3.9
-
3.5
2.26
12
5.4
4.16
FIGHTING ISLAND

Figure 26.Mean mercury concentration (continued)



water (µg/l)
sediment (mg/kg)
13
14
FIGHTING ISLAND
ECORSE RIVER
1.5
0.19
3.6
0.61
0.9
0.11
15
MONGUAGON CREEK
3.2
0.40
16
17
3.3
0.43
MICHIGAN
ONTARIO
18
GROSSE ILE
2.2
-
2.6
1.45
19
20
21
22
LAKE ERIE
3.1
-
2.7
0.70
2.4
0.17

Figure 27.Mean nickel concentration

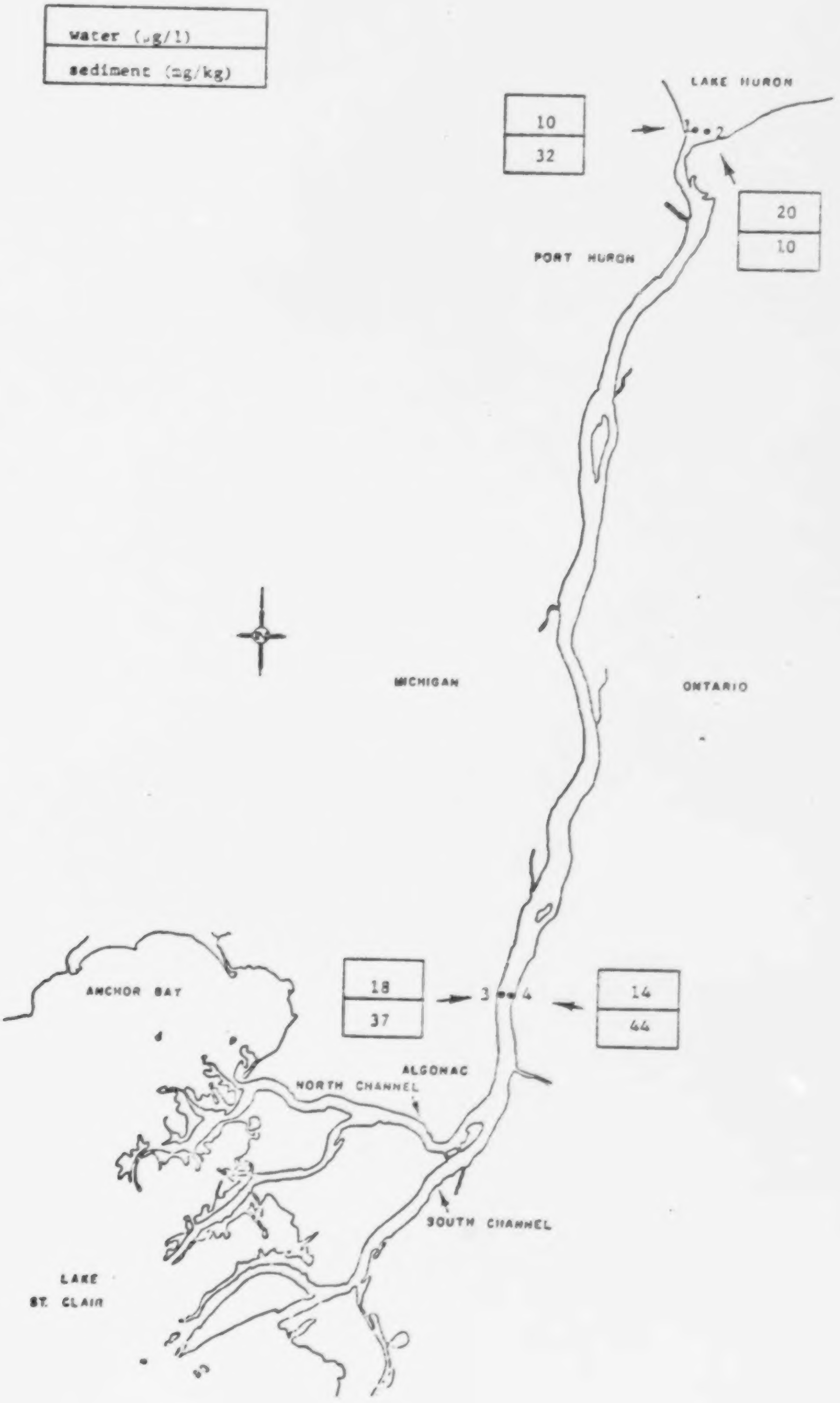

water (µg/l)
sediment (mg/kg)
LAKE HURON
10
32
1
2
20
10
PORT HURON
MICHIGAN
ONTARIO
ANCHOR BAY
18
37
3
4
14
44
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE ST. CLAIR

Figure 27. Mean nickel concentration (continued)

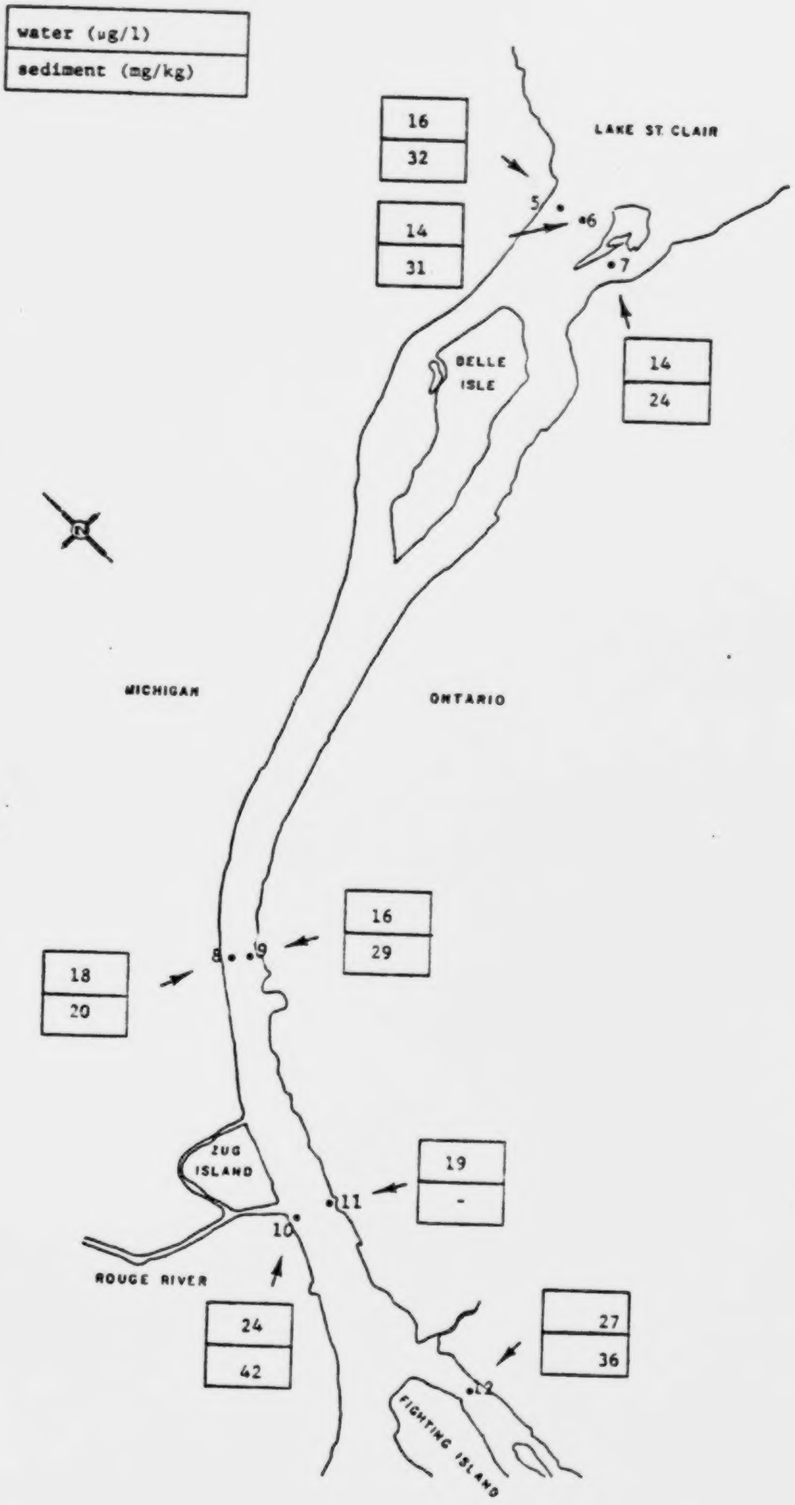
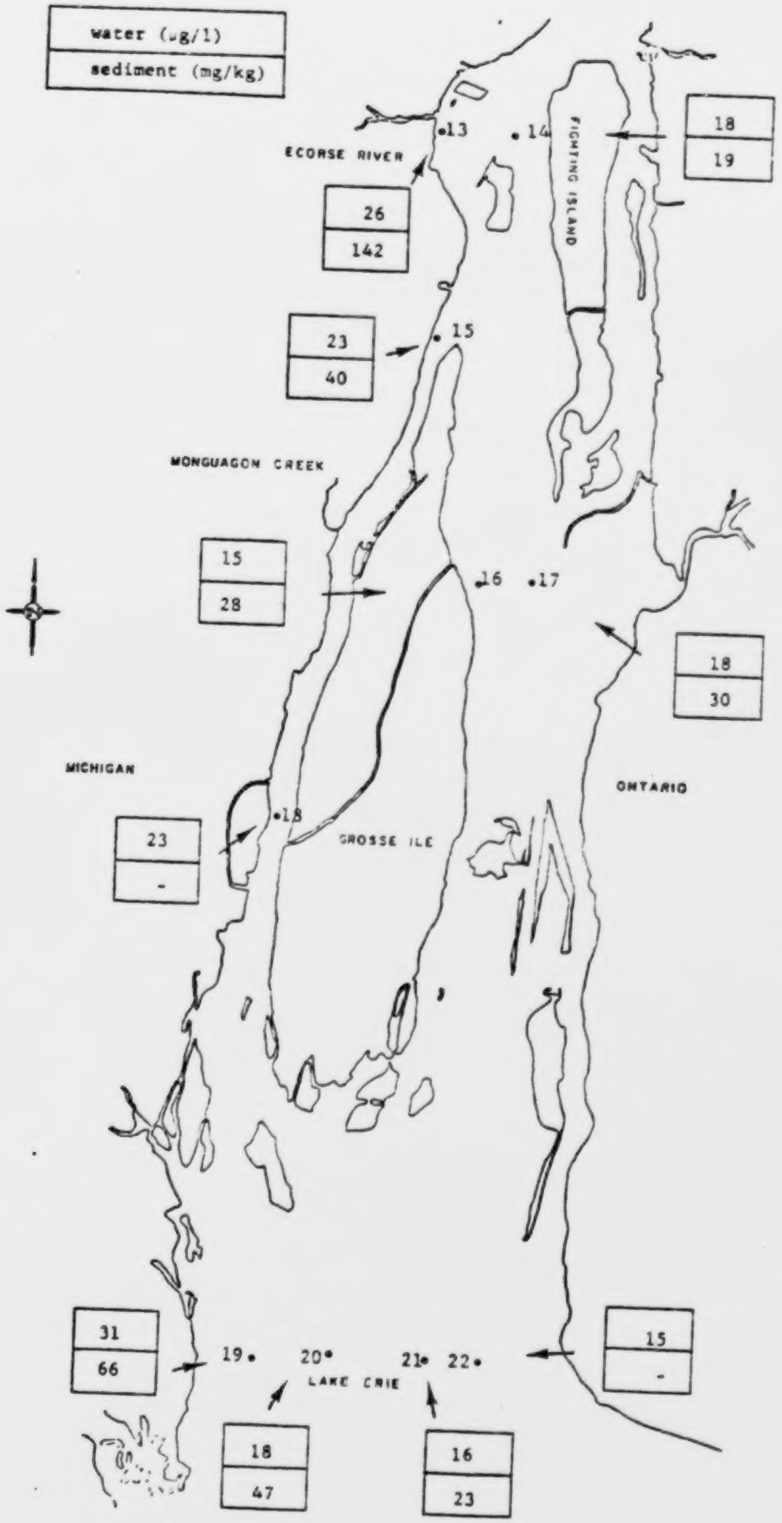

water (μg/l)
sediment (mg/kg)
LAKE ST. CLAIR
16
32
14
31
5
6
7
14
24
BELLE ISLE
MICHIGAN
ONTARIO
16
29
8
9
18
20
ZUG ISLAND
11
19
-
10
ROUGE RIVER
24
42
27
36
12
FIGHTING ISLAND

Figure 27. Mean nickel concentration
(continued)


water (µg/l)
sediment (mg/kg)
13
14
ECORSE RIVER
FIGHTING ISLAND
18
19
26
142
15
23
40
MONGUAGON CREEK
15
28
16
17
18
30
MICHIGAN
ONTARIO
18
23
-
GROSSE ILE
31
66
19
20
21
22
LAKE ERIE
15
-
18
47
16
23

little change in aqueous nickel throughout the St. Clair River and upper Detroit River. Some elevation is seen at stations 10 and 12. The waters along the western shoreline remain somewhat higher in concentration from station 10 to station 19 at Lake Erie. With the exception of station 12, Canadian waters contain approximately the same level of total nickel as influent waters from Lake St. Clair.

Aqueous zinc concentrations are summarized in Figure 28. Mean values for the St. Clair River stations indicate higher zinc concentrations at stations 1 and 4 than stations 2 and 3 by 60 to 100 percent. A mean concentration of 111 μg/l was observed for station 1 at the head of the river, although this relatively high value is primarily the result of a very high concentration observed during the August 1973 survey. Mean levels in the Detroit River vary from 58 to 104 μg/l with generally higher concentrations in the waters along the western shore. However, the waters entering Lake Erie at stations 19-22 are not appreciably different in zinc content than the waters entering the Detroit River from Lake St. Clair.

Total manganese concentrations in the water column are presented in Figure 29. From Figure 29 it is evident that substantial inputs of manganese occur throughout the two river systems, resulting in significantly higher concentrations of aqueous manganese in the waters entering Lake Erie from the Detroit River than in the waters entering the St. Clair River from Lake Huron. The importance of this increase is related mainly to the sorption potential of hydrous manganese oxides for other heavy metals[19,20] Aqueous concentrations of manganese increase approximately 100 percent in the St. Clair River over the mean background level of 3 g/l at stations 1 and 2. The waters entering the Detroit River are further increased in manganese content by about 100 percent over the effluent waters of the St. Clair River. Additional increases in aqueous manganese occur at station 12 and all along the United States shoreline beginning at station 10 and ending at station 19. With the exception of station 12, Canadian waters were not found to contain appreciably more total manganese than the influent waters from Lake St. Clair.

Aqueous iron concentrations, though abundant in compilations of historical data, are of extreme importance in predicting heavy metal behavior in the aqueous environment. Consequently, iron was monitored during all three field surveys. The resulting data is summarized in Figure 30. Analysis of these results reveals that mean iron values, like aqueous manganese, double as the water travels from the head to the mouth of the St. Clair River. As in the case of manganese, the concentration again doubles by the time it reaches stations 5, 6, and 7 at the head of the Detroit River. Indeed, the mean value

Figure 28. Mean zinc concentration

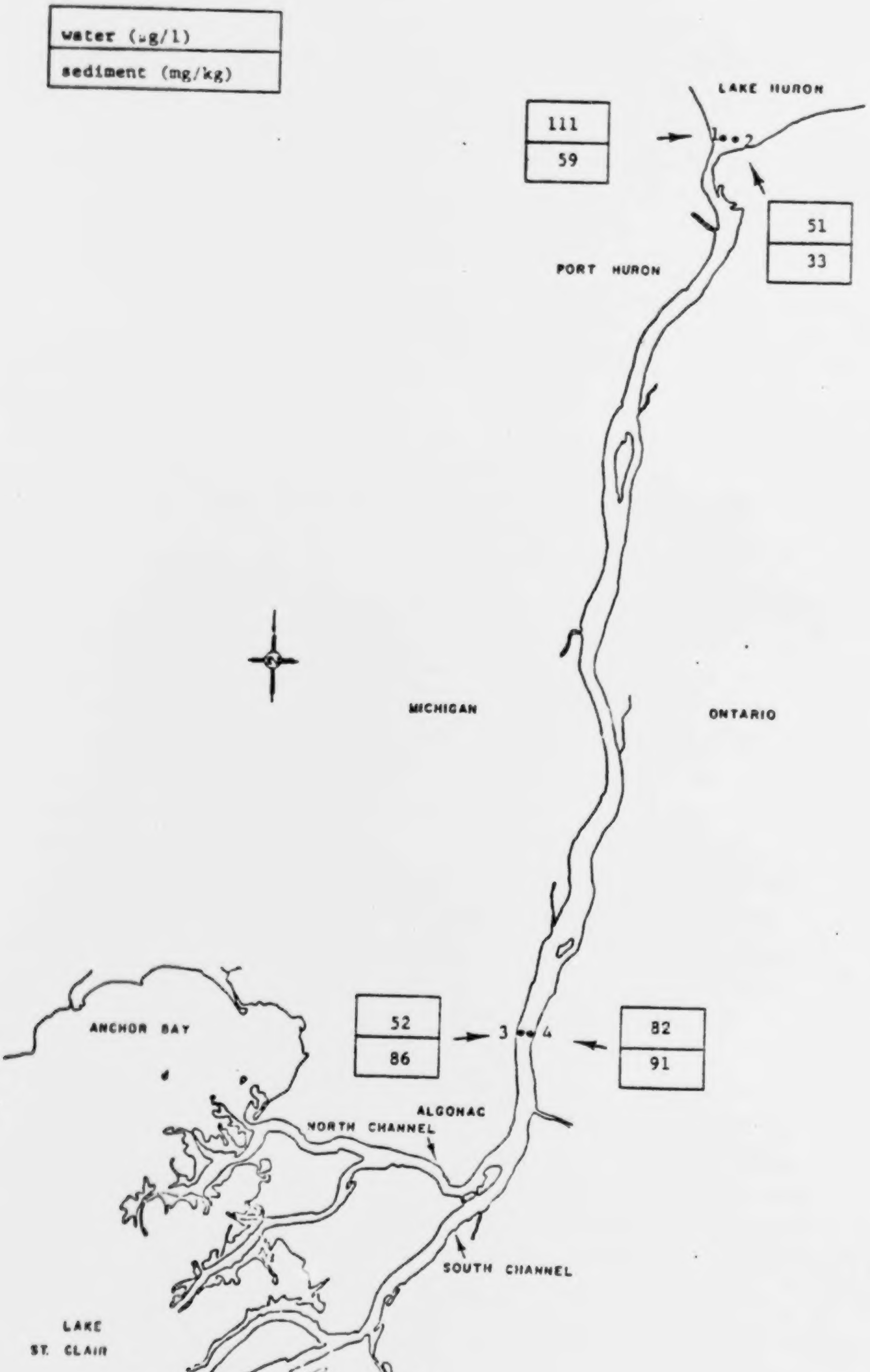

water (µg/l)
sediment (mg/kg)
LAKE HURON
111
59
1
2
51
33
PORT HURON
MICHIGAN
ONTARIO
52
86
3
4
82
91
ANCHOR BAY
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 28. Mean zinc concentration (continued)

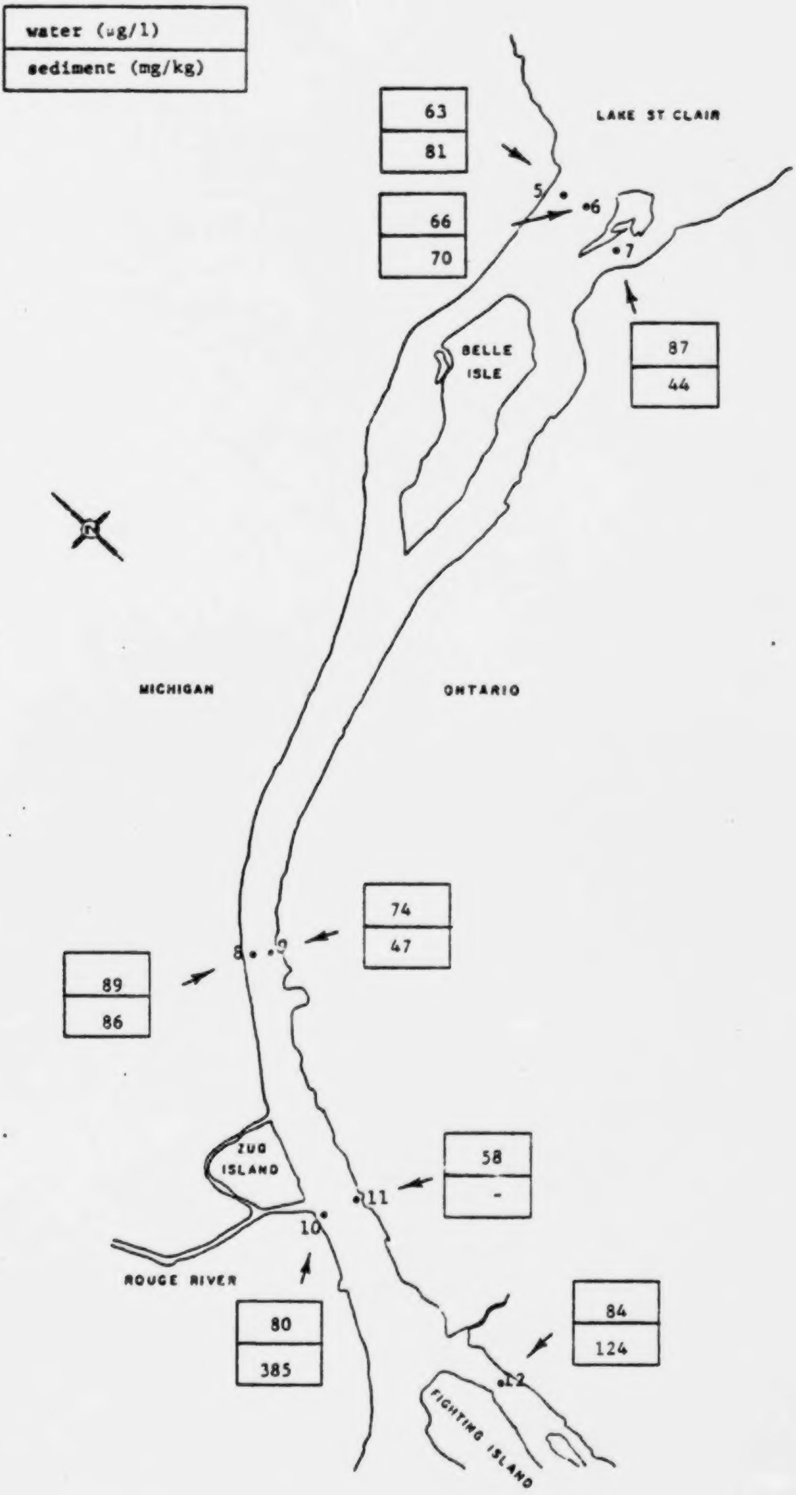

water (µg/l)
sediment (mg/kg)
LAKE ST CLAIR
63
81
66
70
5
6
7
87
44
BELLE ISLE
MICHIGAN
ONTARIO
74
47
8
9
89
86
ZUG ISLAND
58
-
11
10
ROUGE RIVER
80
385
84
124
12
FIGHTING ISLAND

Figure 28. Mean zinc concentration (continued)

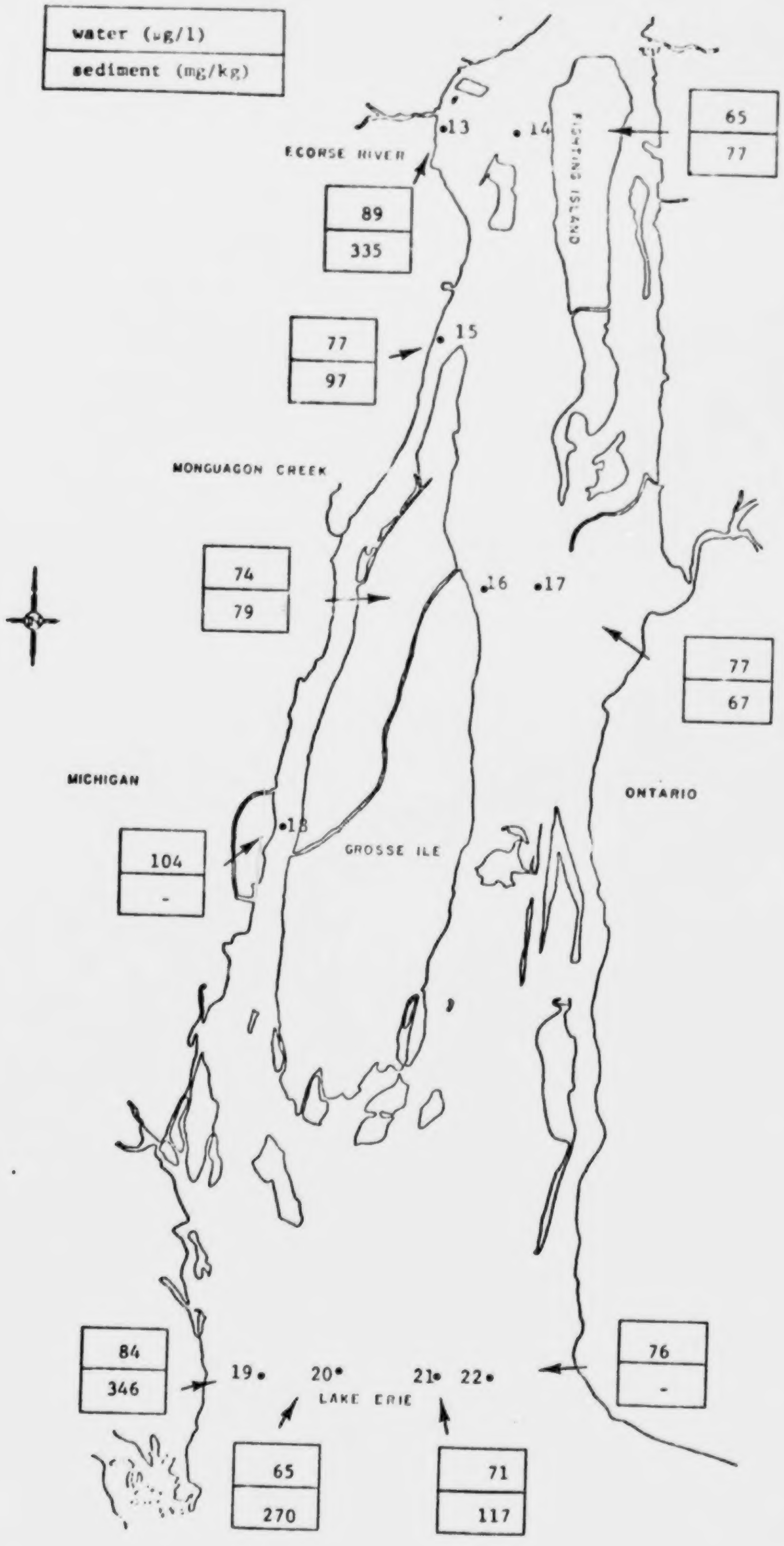
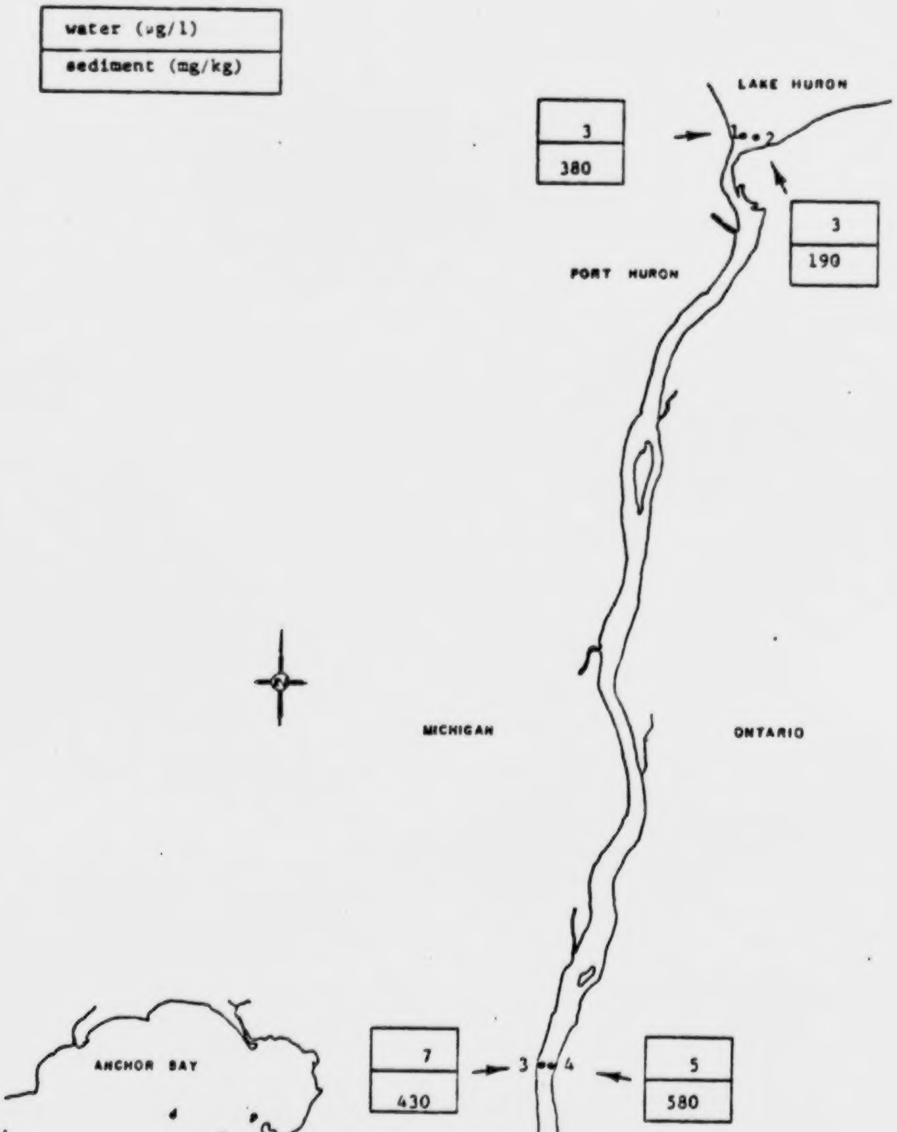

water (µg/l)
sediment (mg/kg)
13
14
ECORSE RIVER
FIGHTING ISLAND
65
77
89
335
77
97
15
MONGUAGON CREEK
74
79
16
17
77
67
MICHIGAN
ONTARIO
18
GROSSE ILE
104
-
84
346
19
20
21
22
LAKE ERIE
76
-
65
270
71
117

Figure 29.Mean manganese concentration



water (µg/l)
sediment (mg/kg)
LAKE HURON
3
380
1
2
3
190
PORT HURON
MICHIGAN
ONTARIO
ANCHOR BAY
7
430
3
4
5
580
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 29. Mean manganese concentration (continued)

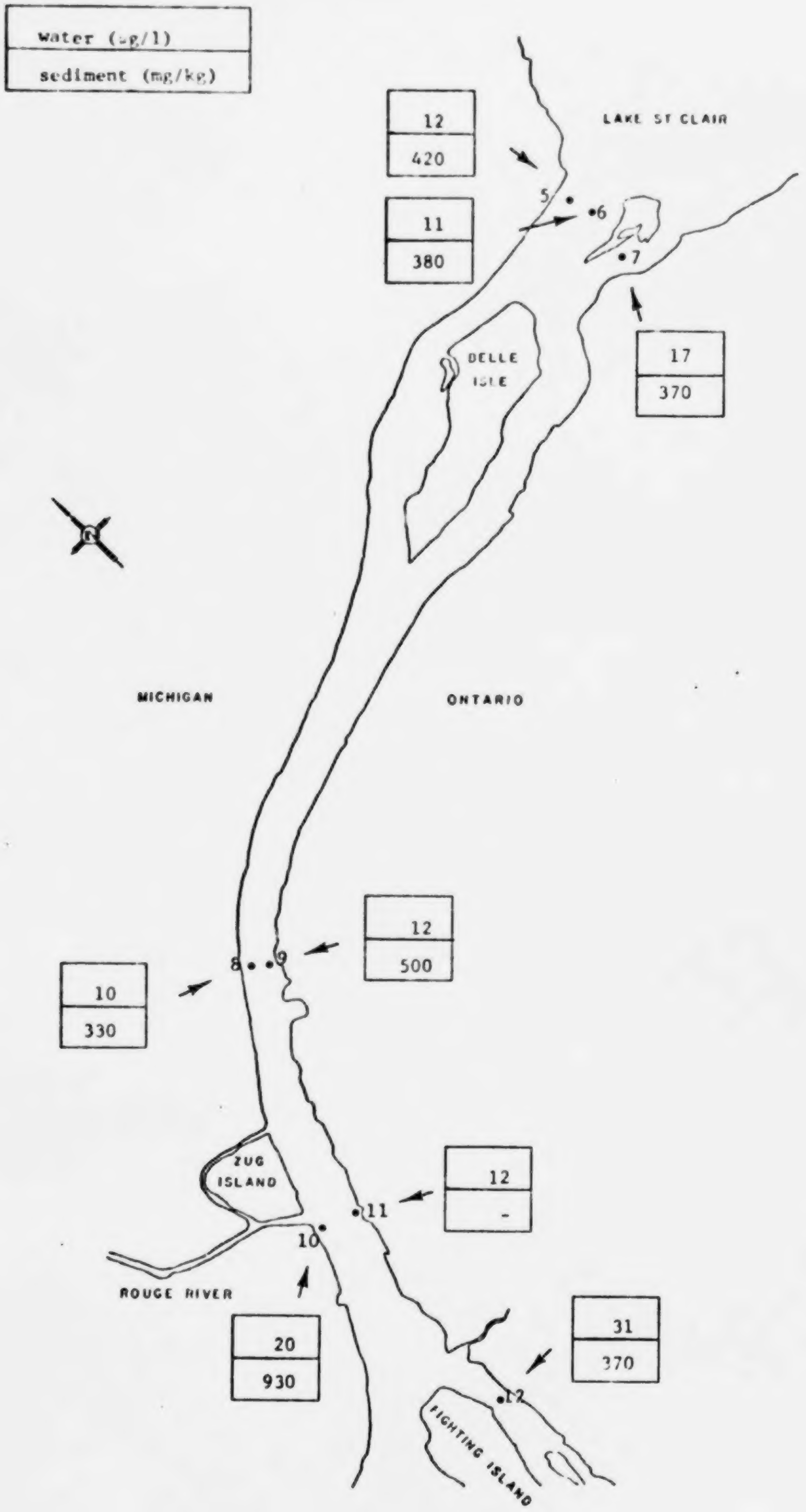

water (µg/l)
sediment (mg/kg)
LAKE ST CLAIR
12
420
11
380
5
6
7
17
370
BELLE ISLE
MICHIGAN
ONTARIO
12
500
8
9
10
330
ZUG ISLAND
12
-
11
10
ROUGE RIVER
20
930
31
370
12
FIGHTING ISLAND

Figure 29. Mean manganese concentration (continued)

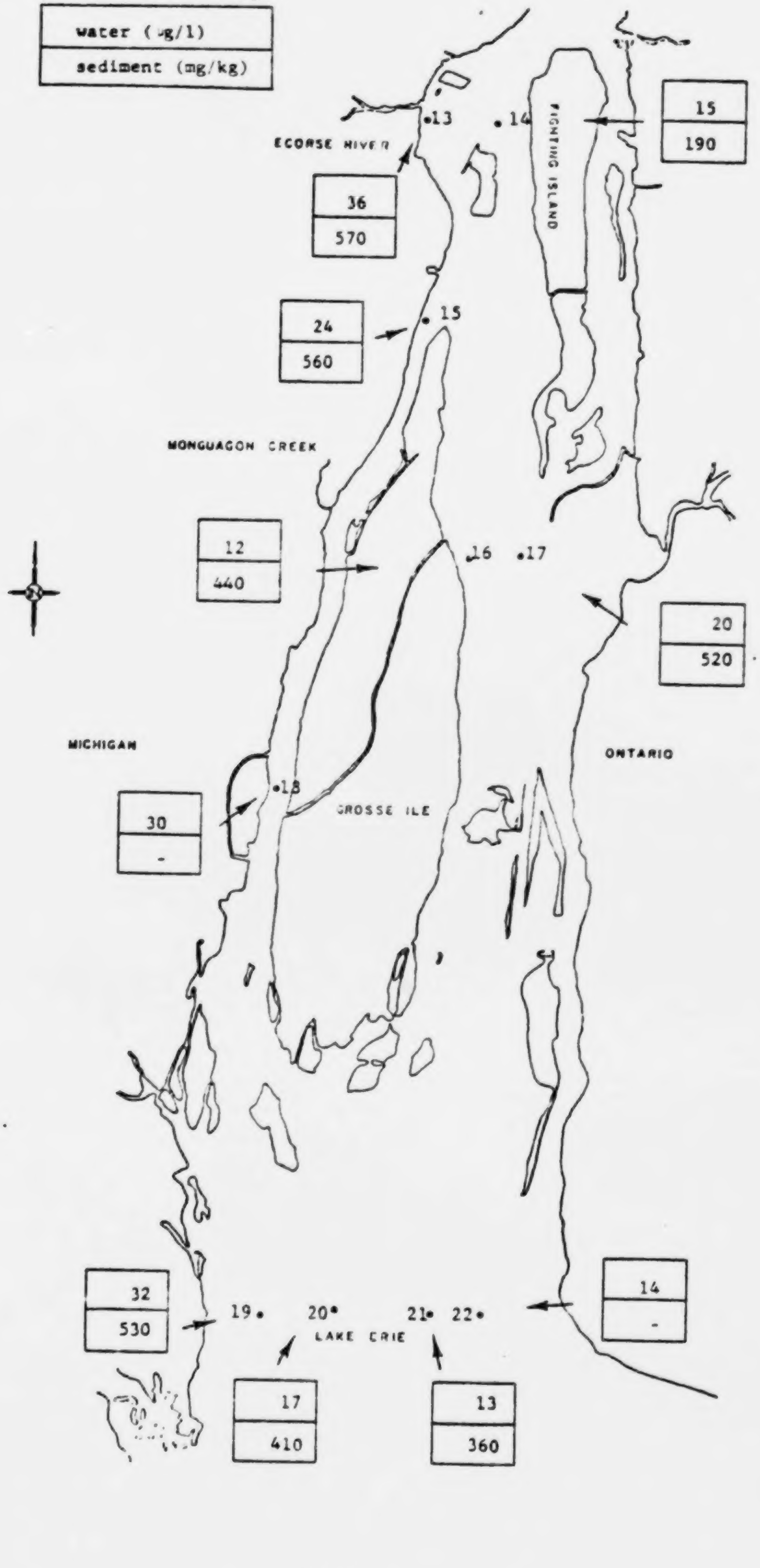

water (µg/l)
sediment (mg/kg)
13
14
ECORSE RIVER
FIGHTING ISLAND
15
190
36
570
24
560
15
MONGUAGON CREEK
12
440
16
17
20
520
MICHIGAN
ONTARIO
18
30
-
GROSSE ILE
32
530
19
20
21
22
LAKE ERIE
14
-
17
410
13
360

Figure 30. Mean iron concentration

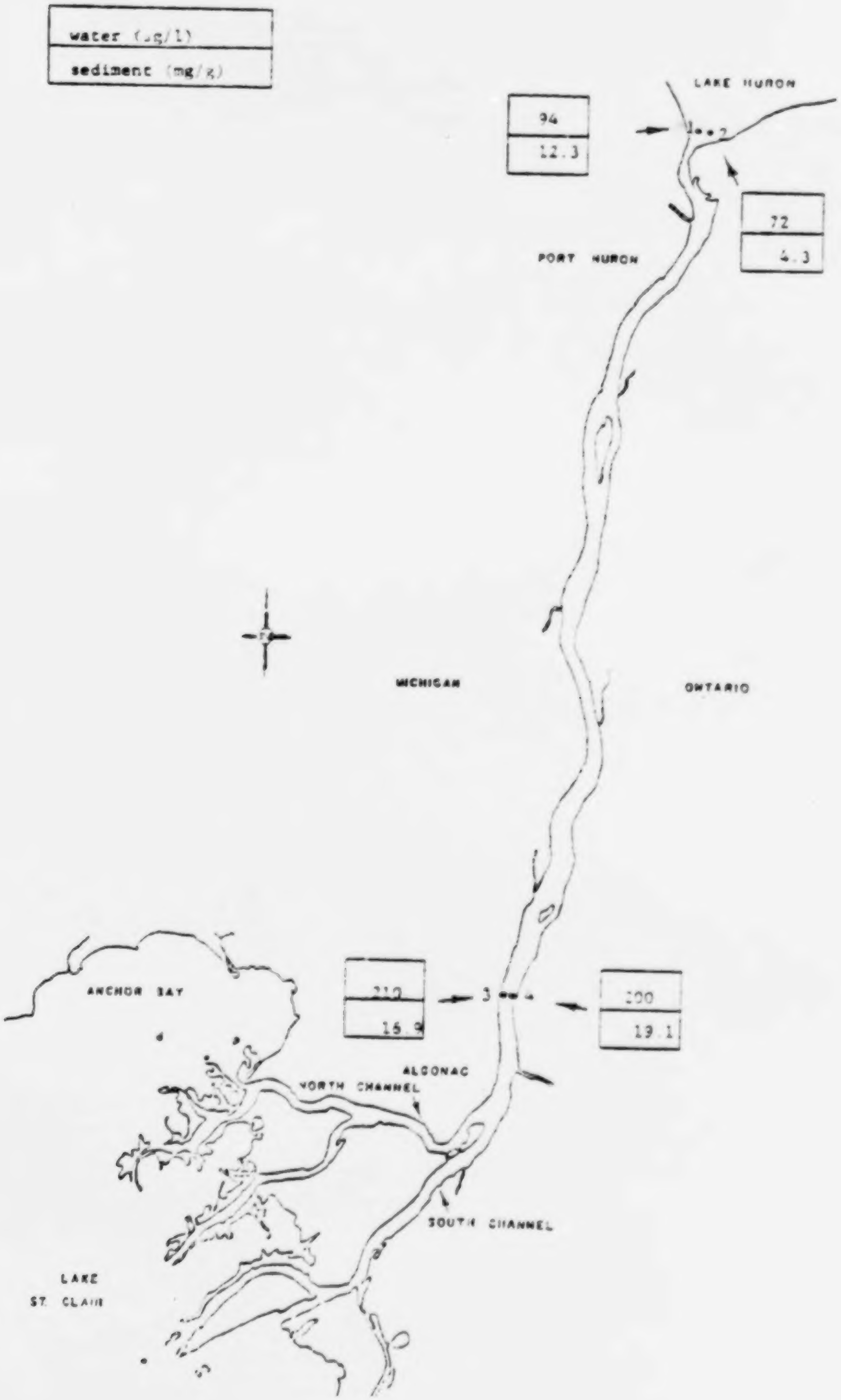
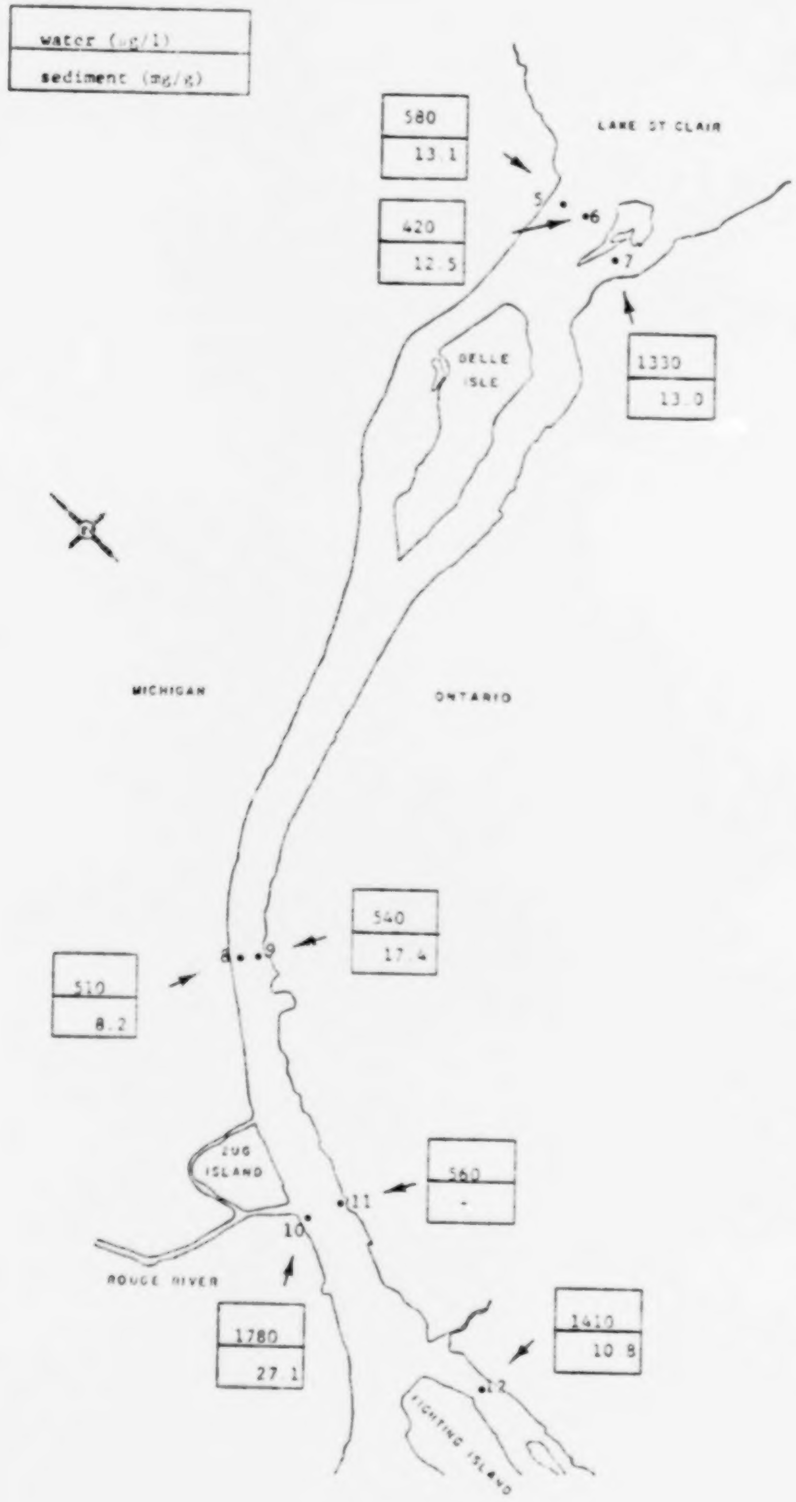
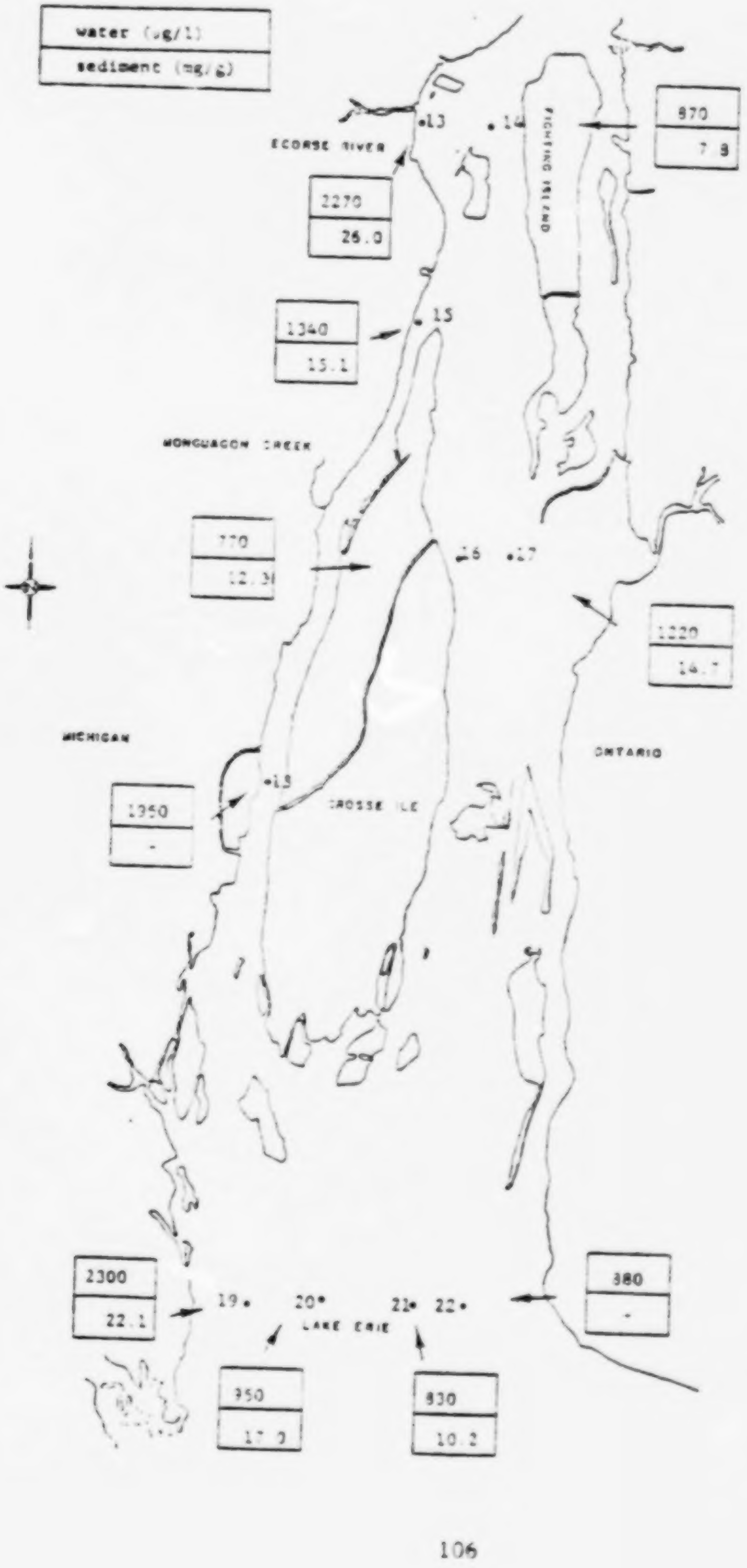

water (µg/l)
sediment (mg/g)
LAKE HURON
94
12.3
1
2
72
4.3
PORT HURON
MICHIGAN
ONTARIO
ANCHOR BAY
210
16.9
3
4
200
19.1
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 30. Mean iron concentration (continued)



water (µg/l)
sediment (mg/g)
LAKE ST CLAIR
580
13.1
5
6
420
12.5
7
1330
13.0
BELLE ISLE
MICHIGAN
ONTARIO
540
17.4
8
9
510
8.2
ZUG ISLAND
560
-
11
10
ROUGE RIVER
1780
27.1
1410
10.8
12
FIGHTING ISLAND

Figure 30 Mean iron concentration (continued)


water (µg/l)
sediment (mg/g)
ECORSE RIVER
•13
•14
FIGHTING ISLAND
870
7.8
2270
26.0
1340
15.1
•15
MONGUAGON CREEK
770
12.30
16
•17
1220
14.7
MICHIGAN
ONTARIO
•18
GROSSE ILE
1950
-
2300
22.1
19•
20•
21•
22•
LAKE ERIE
380
-
950
17.0
830
10.2

recorded for station 7 is more than ten times higher than that of stations 1 and 2. Iron at stations 8, 9, and 11 remain somewhat over 500 μg/l, however the mean level recorded at station 10 was 1780 μg/l. Station 12 is similarly enriched. Waters along the United States shoreline remain heavily enriched in iron through station 19 where the total iron concentration averages 2,300 μg/l. Canadian waters below station 11 are also enriched, with mean values never falling below 830 μg/l.

Pesticides - In addition to the monitoring of heavy metals, an important area of investigation in the chemical field survey program included toxic organic substances, particularly chlorinated pesticides. In an attempt to obtain a preliminary indication of the level of these substances in the water column, samples were collected during the August 1973 survey for analysis of the gross level of chlorinated hydrocarbons present. (In such an analysis the species present in a routine analysis for chlorinated pesticides are not differentiated, but rather the total area of a vapor phase chromatogram is integrated as a unit and the results are present in terms of some arbitrary chlorinated hydrocarbon standard.) Results of these analyses are contained in the appended Table A-4. The first survey indicated fairly uniform levels in the St. Clair River with the exception of station 1 which was about 35 percent higher than the other three stations. Levels in the influent waters to the Detroit River were somewhat lower than in the St. Clair River, but were observed to have increased in concentration by the time they had reached stations 10 and 11. The only further increases were reported at station 18 below most of the industrial outfalls along the Trenton Channel, and station 21 at the interface with Lake Erie. Following requests by the federal project monitor and state environmental agency personnel, the analysis for gross chlorinated hydrocarbon content was replaced by analysis for specific chlorinated pesticides on samples taken during subsequent surveys. Included in the list of pesticides determined were endrin, aldrin, dieldrin, lindane, heptachlor, heptachlor epoxide, DDT, DDD, and DDE. Polychlorinated biphenyls were not included in the discrete analyses, though such substances are included in the chlorinated hydrocarbon analysis carried out on the August 1973 samples. The results of the discrete pesticide analysis are presented in the Appendix, Table A-7. A review of this data reveals substantial variation throughout the St. Clair and Detroit River systems. However, since rigorous interpretation of discrete pesticide levels is beyond the scope of this project, the data presented in this report serves primarily to add to the relatively limited bank of information available on discrete pesticide concentrations in these two river systems.

Sediment Phase -

The sampling program for the sediment phase was conceived primarily to provide information on this relatively neglected portion of the St. Clair and Detroit River systems.

This program was not designed as a comprehensive evaluation of sediment history in the river bottoms, but rather it was intended to provide a preliminary characterization of the sediment condition of these rivers. As a result, analyses were limited to determining total sediment content of a given constituent, rather than differentiating the various forms of the constituent as a function of particle size distribution, Eh, pH, and/or depth.

The parameters to be studied during the sediment surveys were chosen to include carbonaceous loadings, the biological nutrients nitrogen and phosphorus, the most common heavy metals, and chlorinated organic species. A brief description of sediment morphology was recorded for each sample collected. A compilation of all the sediment data generated during the three surveys is contained in the appended Tables A-8 through A-11. Summarized data for many of the parameters are presented in figure form within the body of this report. The values indicated in such figures represent the arithmetic average of all data for a given parameter gathered at a particular station during the three surveys. In some cases the average is calculated from less than three values, and in a few instances no mean value is reported at all. Sediment samples were not always obtainable by the methods employed, therefore, certain sampling stations have no recorded sediment data for one or more of the sampling dates.

Mean values for Chemical Oxygen Demand (COD) are presented in Figure 21. Review of this data indicates an apparent increase in the sediment COD burden as the St. Clair River travels from Lake Huron to Lake St. Clair. This increase amounts to approximately a doubling of the COD concentration. Sediments at the head of the Detroit River (stations 5, 6, and 7) are approximately half that observed at the mouth of the St. Clair River (stations 3 and 4). Progressing down the Detroit River, a substantial increase in the background COD is seen at station 8, while the value recorded in the Canadian waters at that milepoint (station 9) is relatively low. Mean values for stations in Canadian waters below this milepoint are relatively constant at 40-50 mg/kg to the Lake Erie interface. Stations along the United States shore, however, are varied and generally exhibit much higher concentrations than the Canadian counterparts. Sediment concentrations at stations 10, 13 and 19 are about an order of magnitude higher than those at the head of the river. Physical descriptions of the samples taken at these three stations further indicate that these are areas where organic deposition is appreciable.

The Kjeldahl-nitrogen values, recorded in Figure 31, characterize the reduced nitrogen forms present in the river sediments. From this data it is evident that some increase in the mean level of reduced nitrogen forms in the sediment does occur as the waters of the St. Clair River descend from Lake Huron. In comparison to station 1 this increase is

Figure 31.Mean kjeldahl nitrogen concentration

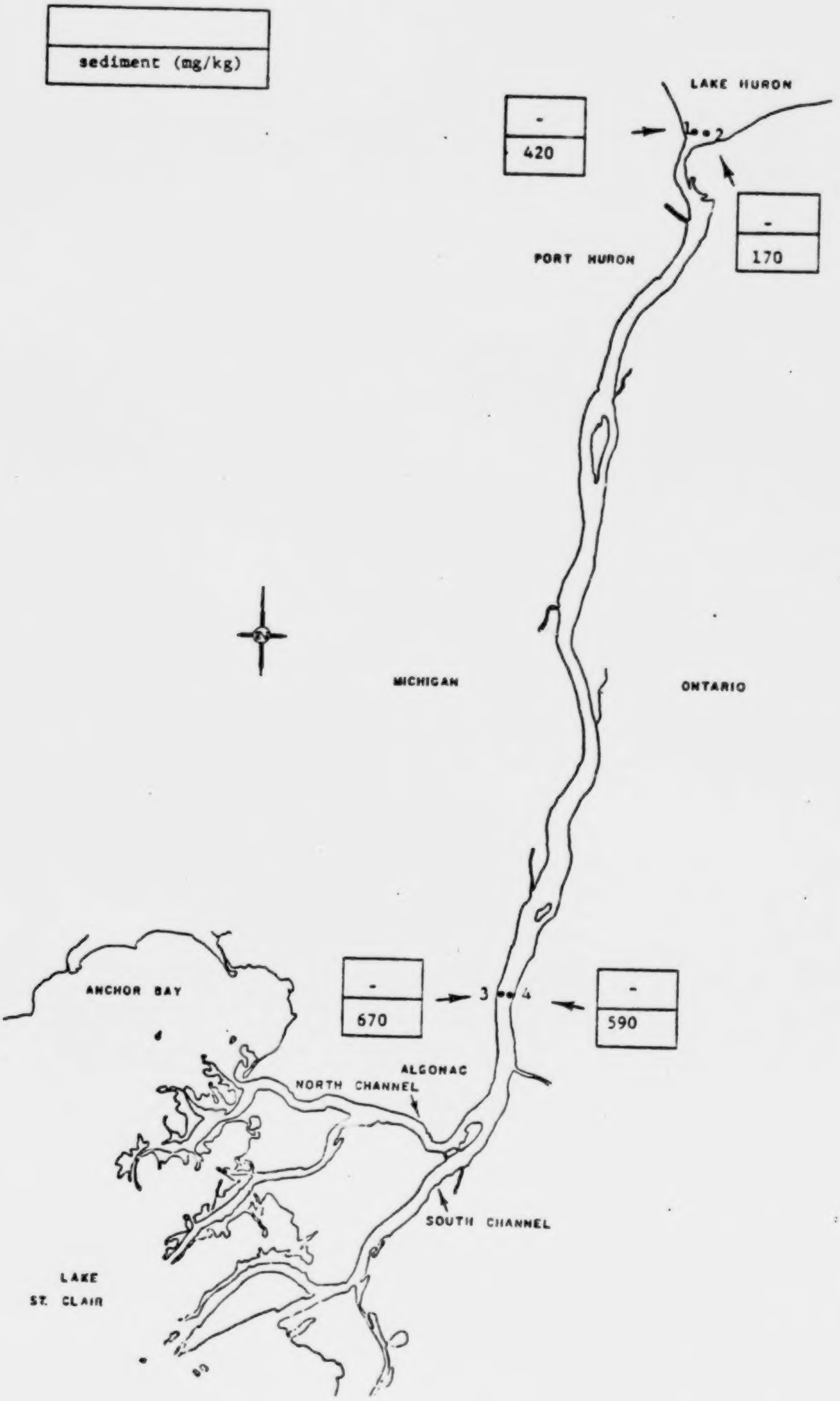

sediment (mg/kg)
LAKE HURON
-
420
1
2
-
170
PORT HURON
N
MICHIGAN
ONTARIO
ANCHOR BAY
-
670
3
4
-
590
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 31. Mean kjeldahl nitrogen concentration (continued)

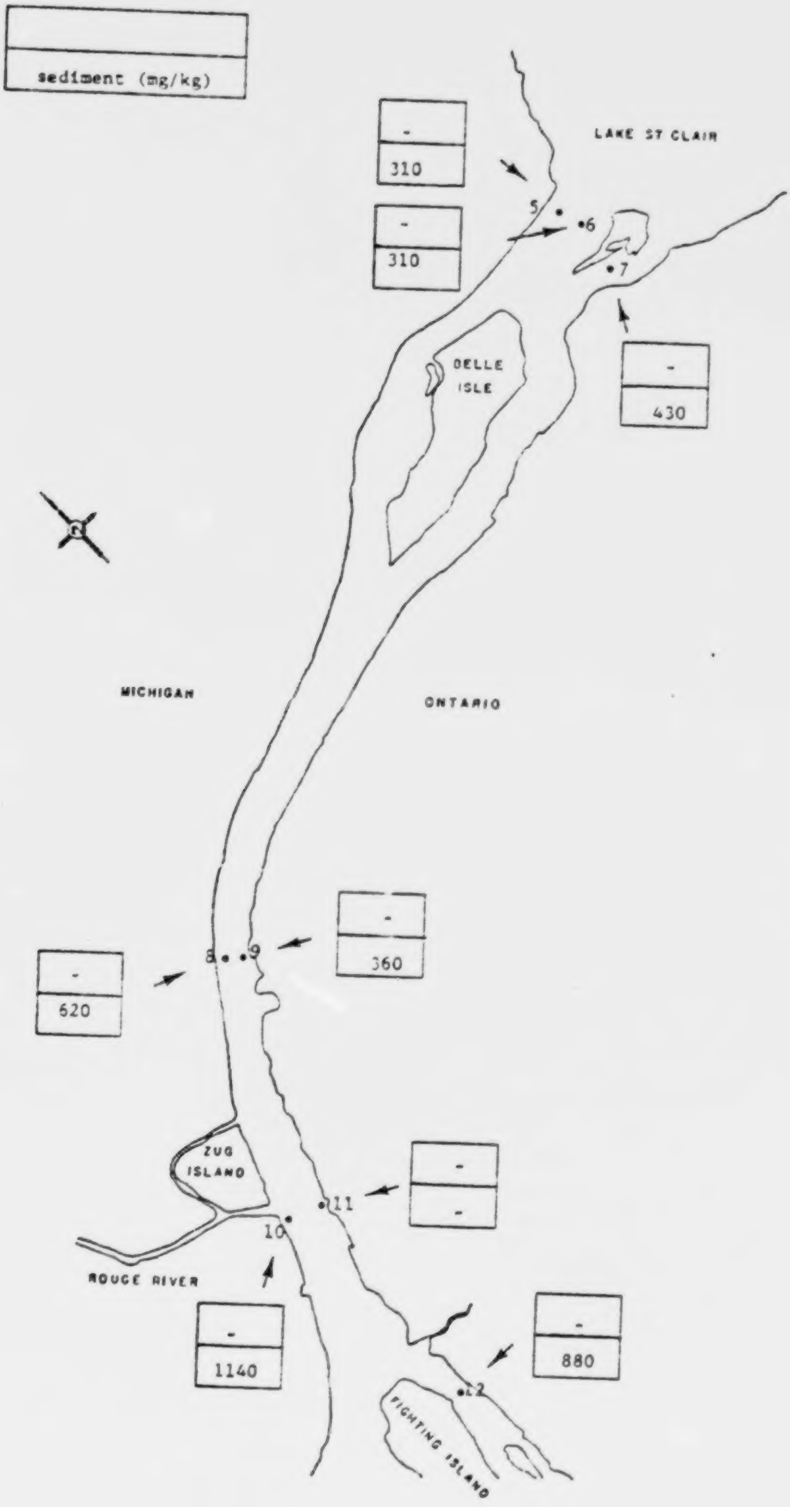
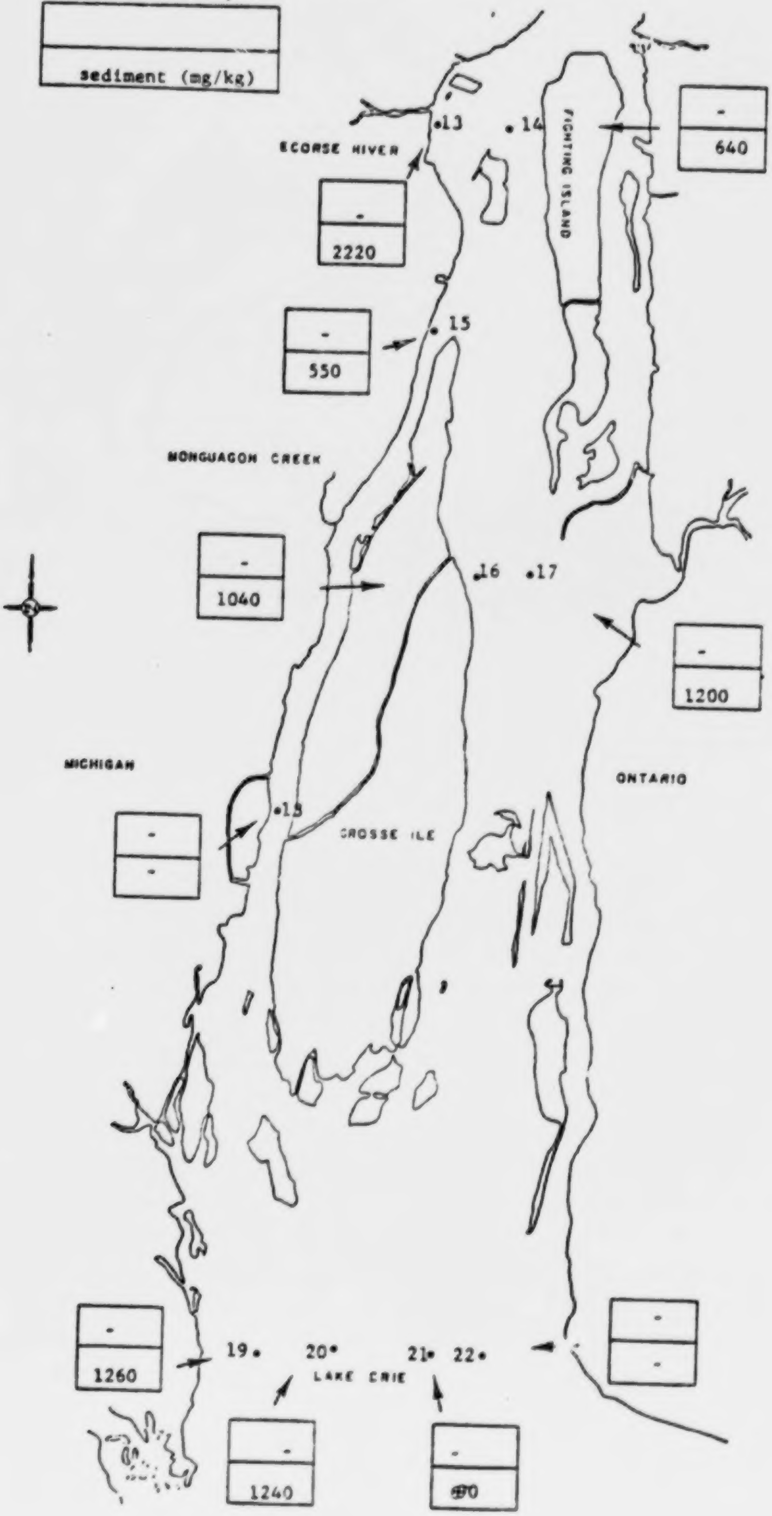

sediment (mg/kg)
LAKE ST CLAIR
5
6
7
310
310
430
BELLE ISLE
MICHIGAN
ONTARIO
8
9
620
360
ZUG ISLAND
11
10
ROUGE RIVER
1140
880
12
FIGHTING ISLAND
-

Figure 31. Mean kjeldahl nitrogen concentration (continued)

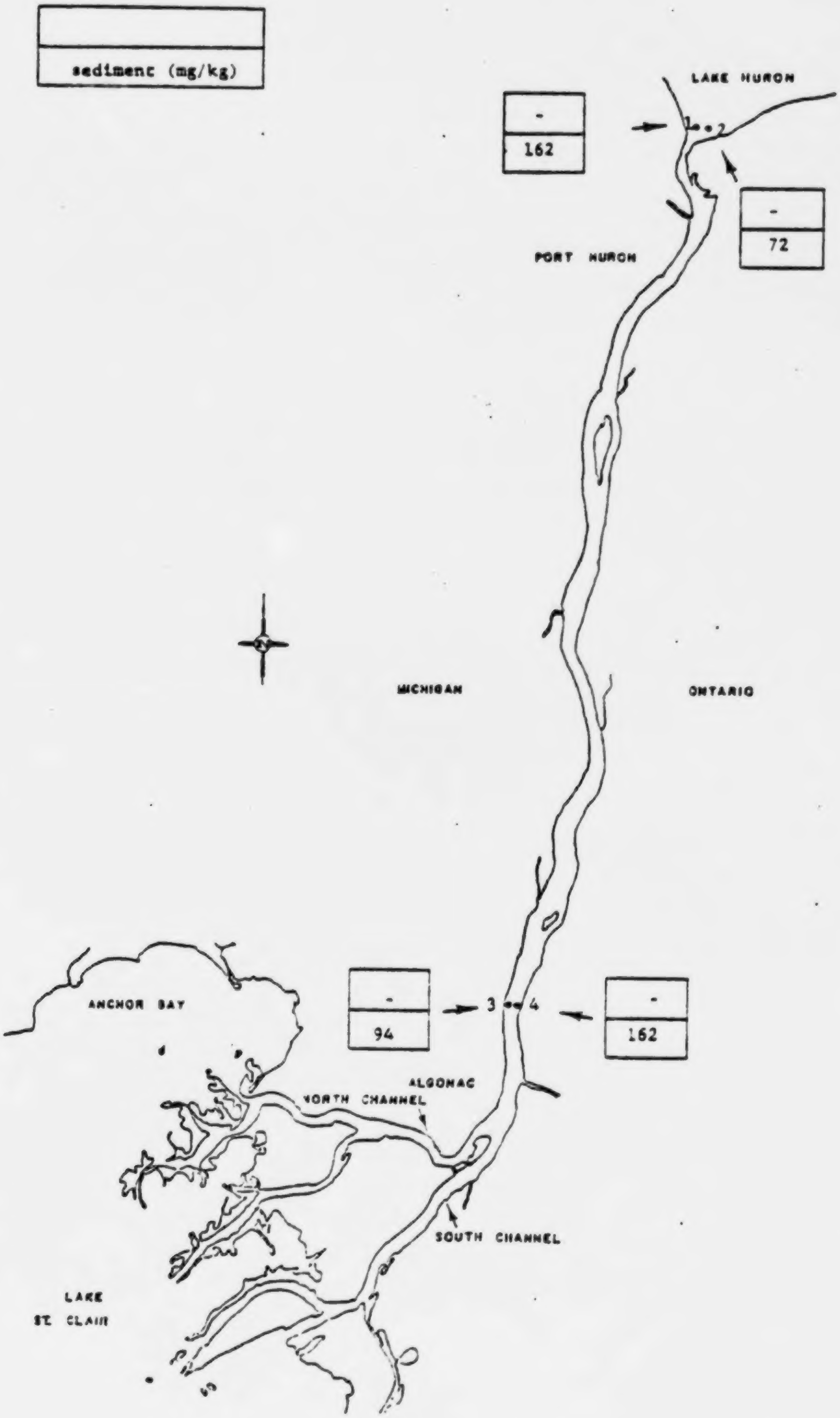

sediment (mg/kg)
ECORSE RIVER
•13
•14
FIGHTING ISLAND
-
640
-
2220
•15
-
550
MONGUAGON CREEK
-
1040
•16
•17
-
1200
MICHIGAN
ONTARIO
•18
GROSSE ILE
-
-
-
1260
19•
20•
21•
22•
LAKE ERIE
-
1240
-
90
-
-

relatively small, but when compared to the very low level recorded at station 2, this increase becomes appreciable. Mean concentrations recorded at the head of the Detroit River are about 300 mg/kg lower than stations 3 and 4 in the St. Clair, ranging between 310 and 430 mg/kg. As in the case of COD, Kjeldahl-nitrogen enrichment occurs at station 8 along the United States shore, while sediments underlying Canadian waters at the same river mile (station 9) show little change from values recorded at the head of the river. The sediments along the United States shore, beginning with station 10, show every appreciable enrichment in reduced nitrogen forms all the way downstream to the Lake Erie interface. Mean values at stations 10, 13, 19 and 20 range between 1140 and 2220 mg/kg. Canadian sediments, beginning at station 12, show significant enrichment also. Mean values recorded at stations 16 and 17 are over 1000 mg/kg, and the mean at station 21 is 690 - almost twice the level recorded at the head of the river.

One of the oxidized forms of nitrogen-nitrate - was measured in the sediment samples and the mean concentrations are recorded in Figure 32. Levels for the St. Clair River do not indicate any appreciable difference in this nitrogen from between the head and mouth of the river. Stations 1 and 4, however, are notably higher (about 100 percent) than stations 2 and 3. Mean values at the head of the Detroit River range from 66 to 93 mg/kg (as nitrogen). Descending down the river, some increase is seen at stations 9 and 10, however the only appreciable differences observed in the Detroit River sediments occur at stations 13, 19, and 20. The mean concentrations recorded at these stations range from 228 to 359 mg/kg.

The level of total phosphorus in the sediment samples was determined to provide information on any accumulation of this biostimulant in the sediment phase. Overall mean concentrations for this parameter are presented in Figure 33. Values for the St. Clair River stations indicate some accumulation of phosphorus in the surface sediments as the river descends from Lake Huron. As was observed for Kj eldahl and nitrate nitrogen, phosphorus levels at station 2 appear to be appreciably lower than other areas surveyed in the St. Clair River (370 mg/kg versus 620 to 960 mg/kg). Mean phosphorus concentrations at the head of the Detroit River range between 570 and 850 mg/kg. Sediment levels further downstream in the Detroit River show appreciable enrichment over these background levels at stations 10, 13, 15, 17, 19, and 20. Enrichment in the mean concentrations of stations 15 and 17 amounts to about 30 percent. At station 10 the increase is approximately 100 percent. Sediment from station 13 averages more than 3600 mg/kg. Station 20 at the Lake Erie interface records a mean concentration of 1070 mg/kg. Station 19, however, is by far the most phosphorus rich sediment observed during the study. With an exceptionally high average of 5160 mg/kg, the sediment at this

Figure 32.Mean nitrate nitrogen concentration



-
sediment (mg/kg)
LAKE HURON
-
162
1
2
-
72
PORT HURON
MICHIGAN
ONTARIO
-
94
3
4
-
162
ANCHOR BAY
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 32. Mean nitrate nitrogen concentration (continued)

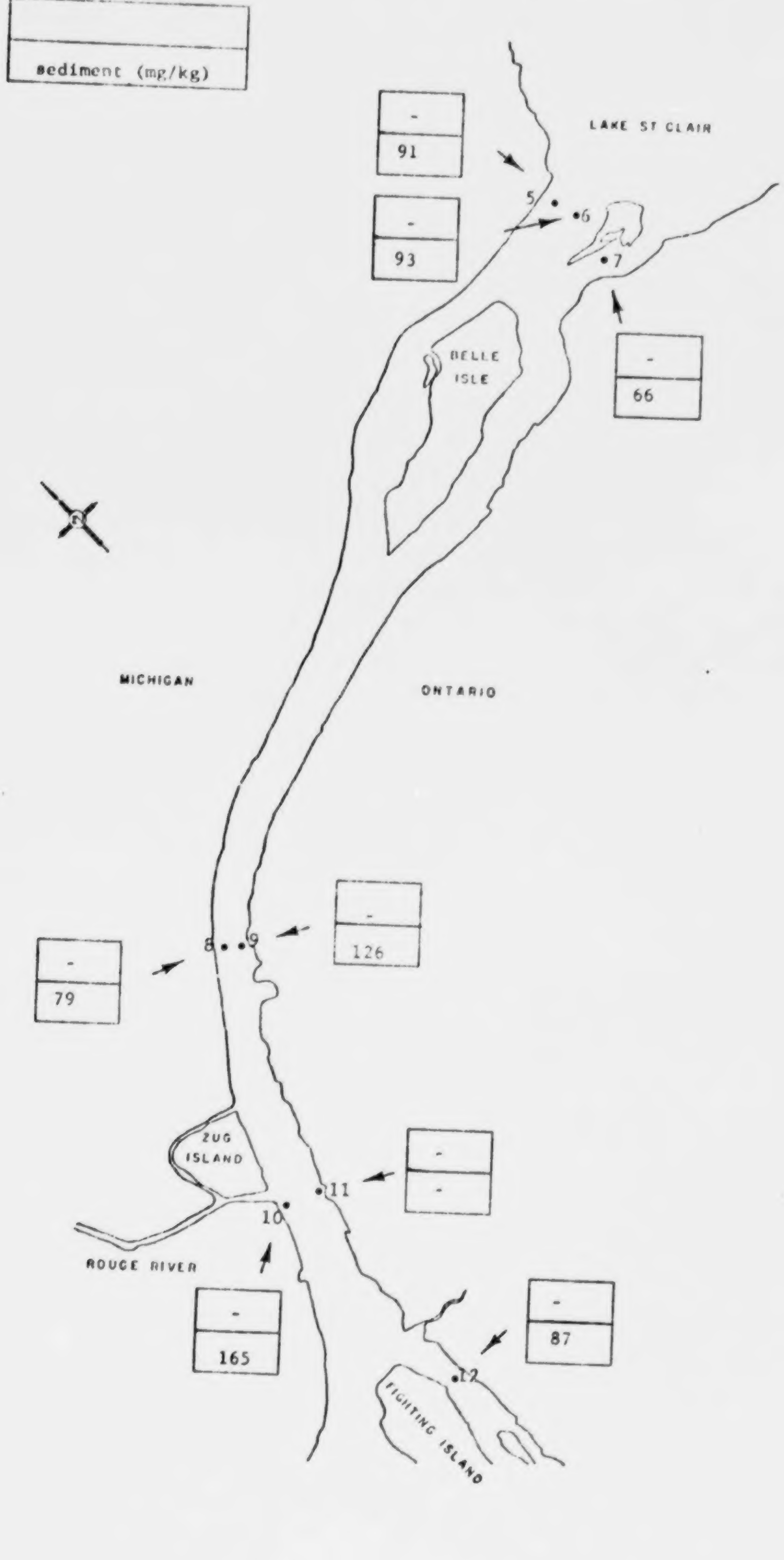

sediment (mg/kg)
LAKE ST CLAIR
-
91
-
93
5
6
7
-
66
BELLE ISLE
MICHIGAN
ONTARIO
-
126
8
9
-
79
ZUG ISLAND
-
-
11
10
ROUGE RIVER
-
165
-
87
12
FIGHTING ISLAND

Figure 32. Mean nitrate nitrogen concentration (continued)

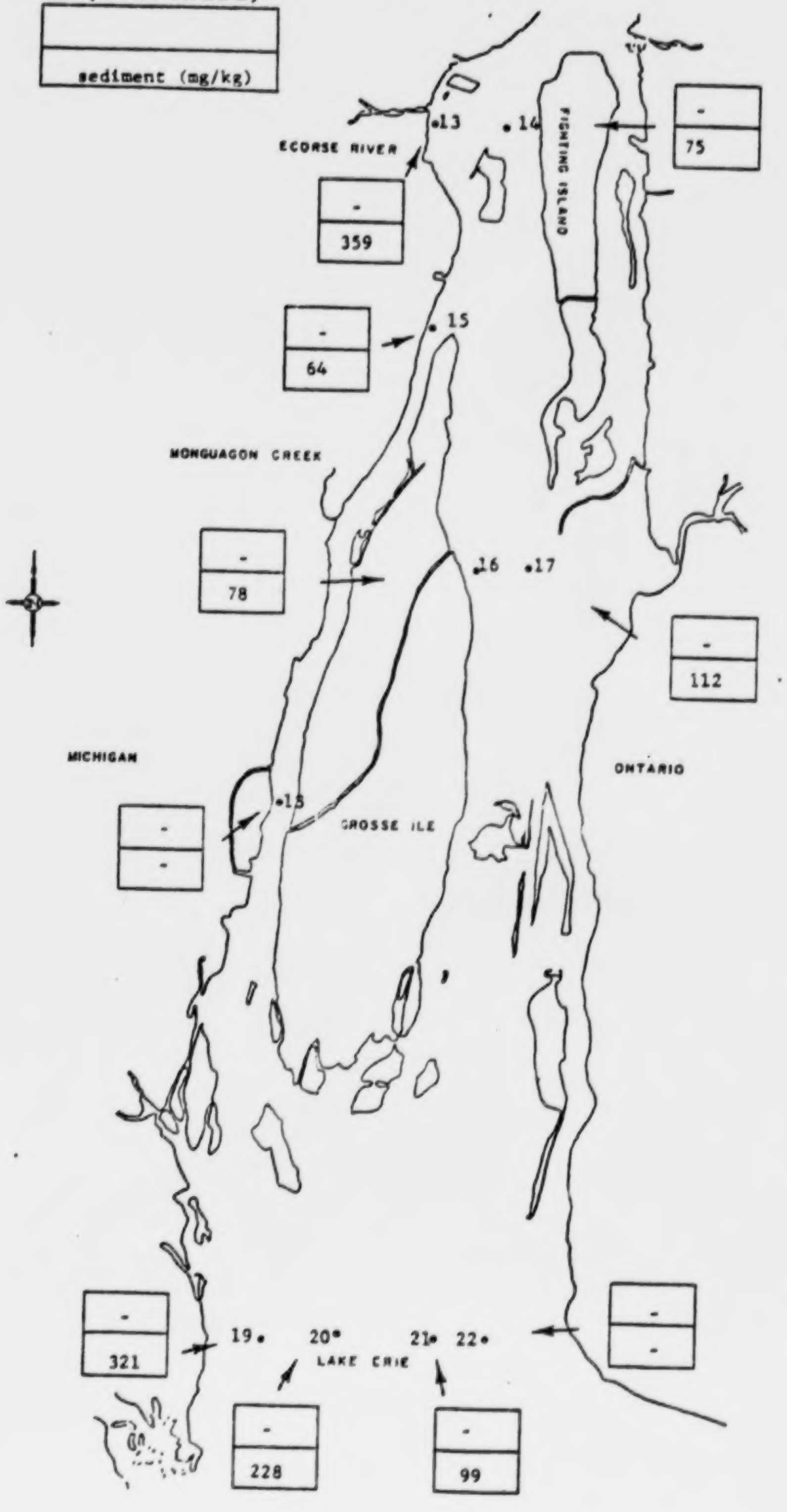

sediment (mg/kg)
•13
•14
ECORSE RIVER
FIGHTING ISLAND
-
75
-
359
•15
-
64
MONGUAGON CREEK
-
78
•16
•17
-
112
MICHIGAN
ONTARIO
•18
GROSSE ILE
-
-
19•
20•
21•
22•
LAKE ERIE
-
321
-
-
-
228
-
99

Figure 33.Mean total phosphorous concentration

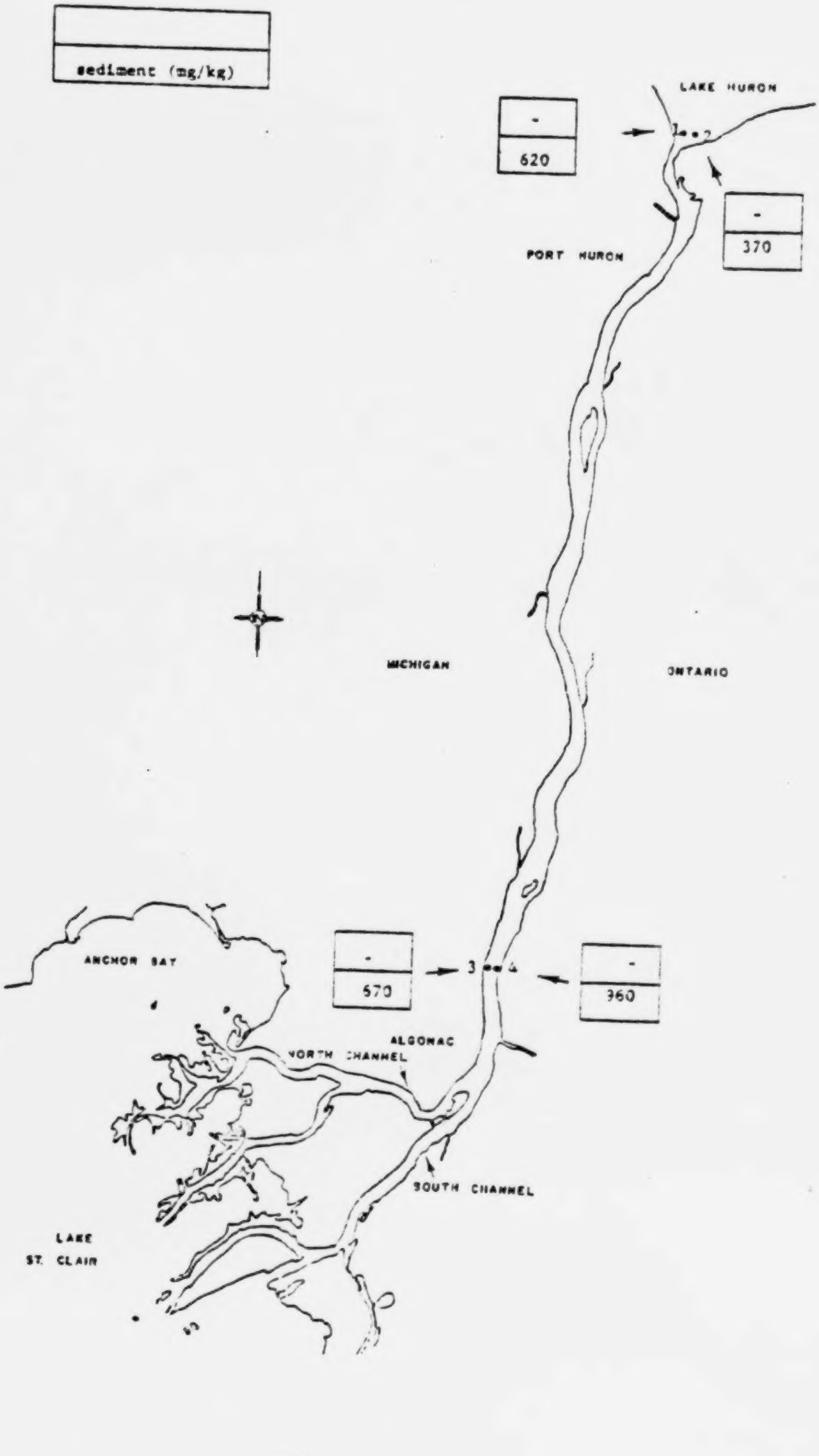

sediment (mg/kg)
LAKE HURON
-
620
1
2
-
370
PORT HURON
MICHIGAN
ONTARIO
ANCHOR BAY
-
570
3
4
-
360
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 33. Mean total phosphorous concentration (continued)

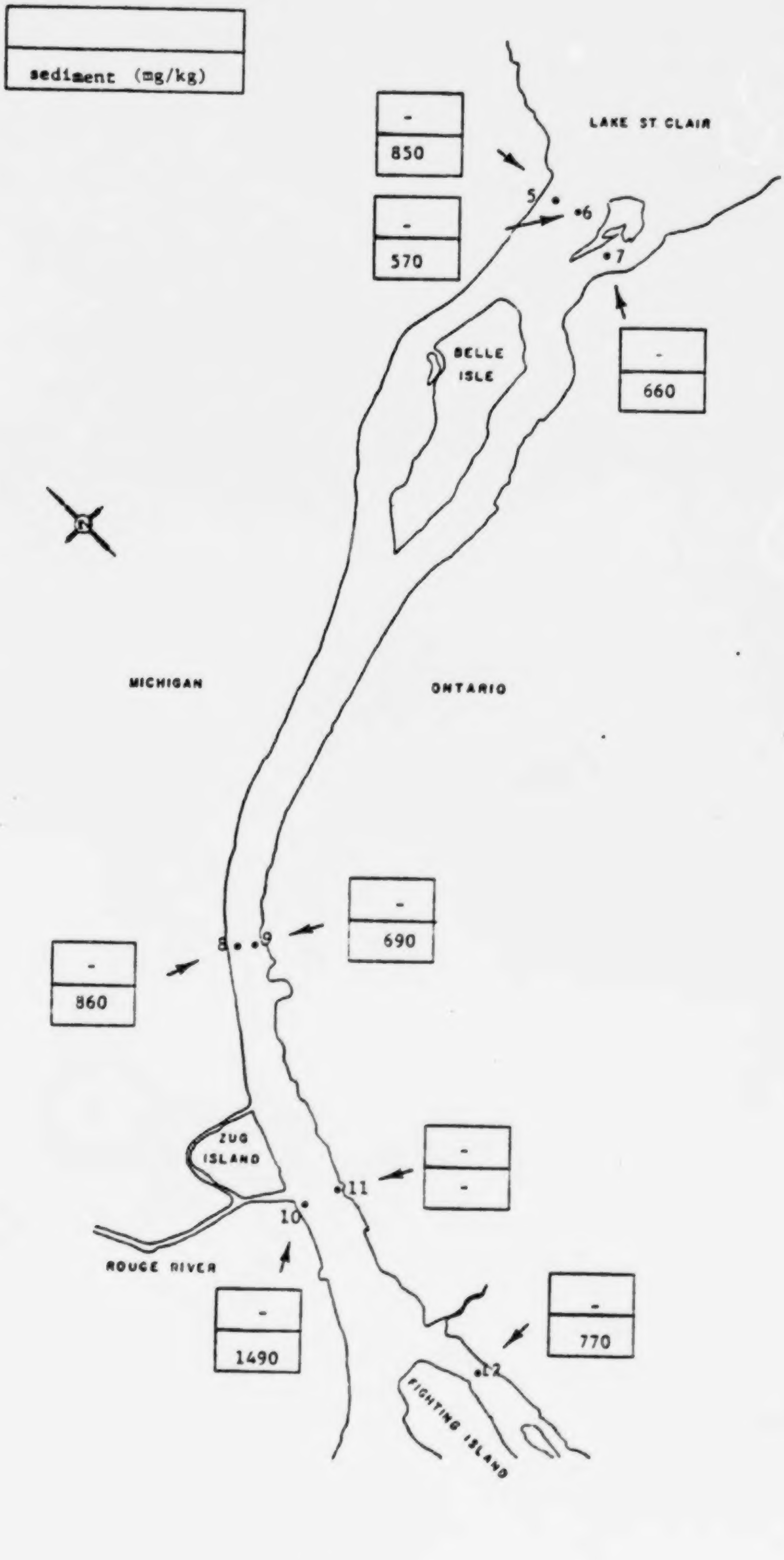
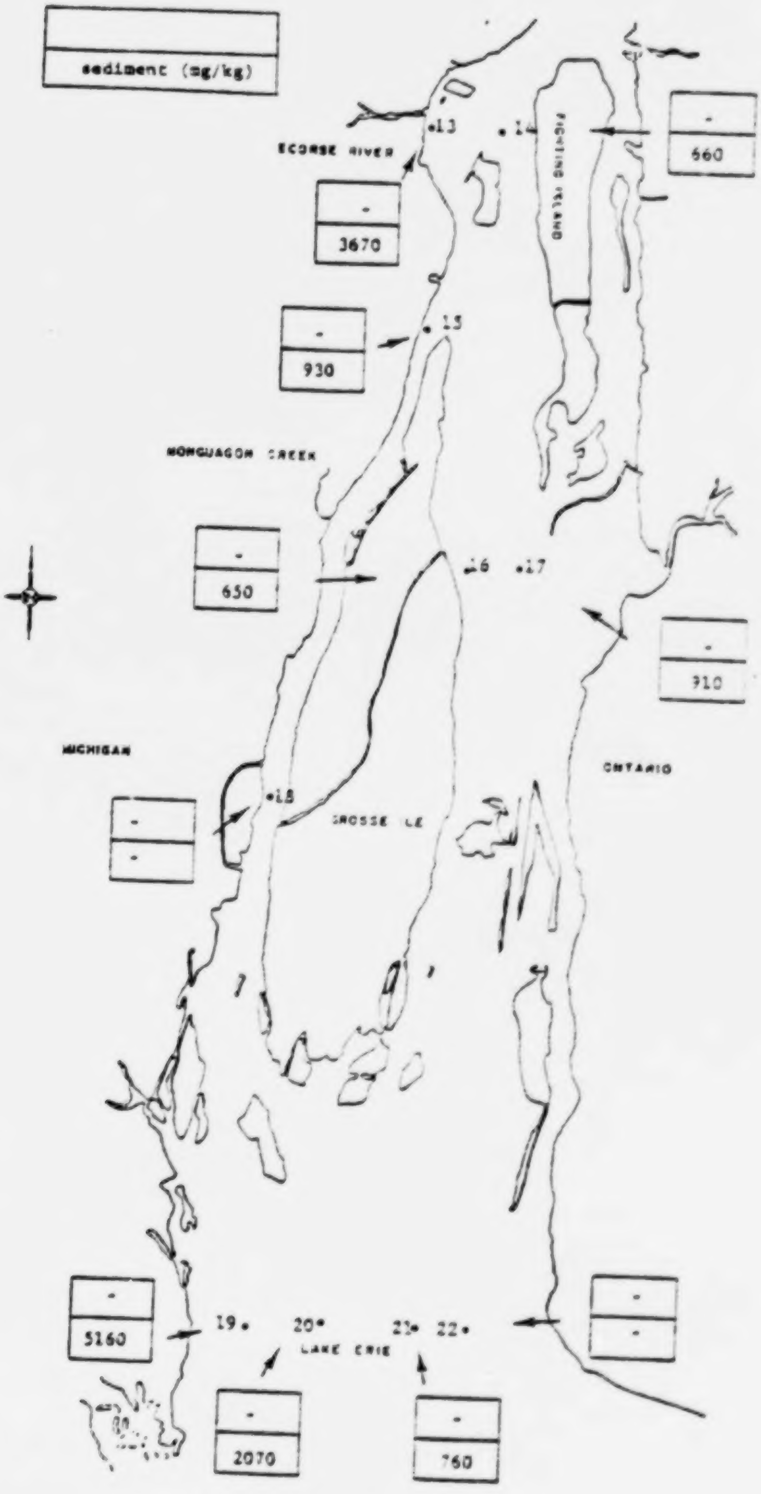

sediment (mg/kg)
LAKE ST CLAIR
-
850
5
6
-
570
7
-
660
BELLE ISLE
MICHIGAN
ONTARIO
-
690
8
9
-
860
ZUG ISLAND
-
-
11
10
ROUGE RIVER
-
1490
-
770
12
FIGHTING ISLAND

Figure 33. Mean total phosphorous concentration (continued)


sediment (mg/kg)
-
660
.13
.14
ECORSE RIVER
FIGHTING ISLAND
-
3670
-
930
.15
MONGUAGON CREEK
-
650
.16
.17
-
910
MICHIGAN
ONTARIO
-
-
.18
GROSSE ILE
-
5160
19.
20.
21.
22.
LAKE ERIE
-
-
-
2070
-
760

station is enriched by more than 4000 mg/kg over sediment at the head of the Detroit River.

Sediment samples were analyzed for the same heavy metals as in the aqueous samples. These analyses included cadmium, chromium, copper, iron, lead, manganese, mercury, nickel, and zinc. As previosuly noted, discrete analytical results are contained in appended Tables A-8 through A-10, while analytical averages are presented in figure form throughout the text of this report.

Average cadmium concentrations for the St. Clair and Detroit River systems are presented in Figure 22. Values for the stations in the St. Clair range from 0.5 to 2.9 mg/kg, with station 2 reporting the very low level of 0.5 mg/kg.Essentially no difference is seen in the level of sedimentary cadmium between the upstream and downstream stations of this river. Levels of 0 to 4 mg cadmium per kg dry sediment are common for glacially derived sediment. Thus the levels observed in the St. Clair River indicate little anthropogenesis of this very toxic heavy metal. Cadmium concentrations at stations 5, 6 and 7 in the Detroit River are similarly low. As the river descends toward Lake Erie, however, enrichment in cadmium is observed at stations 10, 13, 19 and 20. At station 10 a mean concentration of 6.2 mg/kg is reported. The mean value at station 13 is 8.5 mg/kg - more than four times the background levels at the head of the river. The sediments at stations 19 and 20 contain 7.6 and 6.5 mg/kg respectively. This amounts to a net enrichment of approximately 200 percent over background levels. Elsewhere in the Detroit River, enrichment in sedimentary cadmium is neglibible.

The summarized results of sediment chromium analyses are presented in Figure 23. Mean concentrations upstream in the St. Clair River range between 20 to 30 mg/kg. The downstream stations 3 and 4 report mean levels of 39 and 80 mg/kg respectively. The increase at station 4 appears to be relatively significant. Similarly, the mean concentration recorded at station 5 in the Detroit River is considerably higher than those recorded at stations 6 and 7. Background levels of 30 to 40 mg/kg are present in most of the less polluted areas of the Detroit (e.g. stations 6, 7, 14, 16 and 17). Chromium enrichment occurs principally at stations 10, 13, 19 and 20. From the mean values reported in Figure 23, some enrichment may also be occurring at stations 8 and 21. An exceptionally high chromium concentration (2680 mg/kg) was recorded at station 13 during the August 1973 survey, which accounts in large part for the very high mean value reported for this station. A notable phenomenon concerning chromium in the sediments lies in the fact that, in general, the concentrations determined were lower on each succeeding survey. Whether this resulted from scouring, release of this material due to solubility relationships, or some other phenomenon could not be determined.

Sediment copper concentrations are presented in Figure 24. The mean concentrations recorded in the St. Clair River range from 11 to 16 mg/kg, with the highest value recorded at station 1 and the lowest at station 2. The limited range of the values observed in the St. Clair River indicates little anthropogenic influx of this trace metal. Copper levels in the sediment at the head of the Detroit River are comparable to those of several in the St. Clair River. Substantial enrichment along the United States shore occurs as early as station 8. The mean concentration at station 10 is 87 mg/kg. At station 13 the average is 116 mg/kg - nearly an order of magnitude higher than background levels at the head of the river. Stations 19 and 20 also show the presence of anthropogenic copper. Sediments in Canadian waters undergo little, if any, enrichment.

Average lead concentrations are presented in Figure 25. Values from the St. Clair River show appreciable variation. While a relatively low level (6 mg/kg) is recorded at station 2, stations 1 and 4 exhibited values of approximately 30 mg/kg. A relatively high level of 104 mg/kg was recorded at station 3, although this value is largely the result of an exceptionally high concentration recorded on the sample taken in August 1973 (see appended Tables A-8 through A-10). Sediments at the head of the Detroit River range from 15 to 30 mg/kg, values which are common in deep-water sediments of glacial origin. With the exception of certain stations along the United States shore, mean sediment lead levels throughout the river fall into this range. At stations 8, 10, 13, 19 and 20, the effect of anthropogenic lead is obvious from the very high mean concentrations observed. A slight increase over background levels is observed at stations 13 and 21 also.

Mercury concentrations in the river sediments were determined on samples taken during the November and May surveys. The summarized results of these analyses are presented in Figure 26. Mean values for the St. Clair River sediments are relatively low, ranging from 0.06 to 0.53 mg/kg. Station 4 records the highest concentration in the St. Clair River, 0.53 mg/kg, though interpretation of this fact is hindered by the very limited number of samples analyzed for mercury. Sediments at the head of the Detroit River have mercury content similar to those of the St. Clair River, averaging 0.19 to 0.50 mg/kg. All downstream stations in the Detroit, with the exception of 10, 12, 13, 19 and 20, fall into this general range. Mean levels for stations 13 and 20 are only slightly higher than the background concentrations. The mean values for stations 19 and 10, however, are three and four times the maximum background, respectively. The average concentration for station 12 is approximately an order of magnitude higher than background levels.

This high value is due to the relatively high mercury content of the November sediment sample from station 12 (see appended Table A-9). In order to evaluate the credibility of this value, the analytical accuracy of this particular determination was checked and found to be correct. In addition, it is interesting to note that the high sediment content recorded at this point during November correlates well with a relatively high aqueous mercury concentration observed at station 12 during the same sampling period (see appended Table A-5).

Sediment nickel content was determined on all river bottom samples taken during the August, November, and May surveys. The summarized results of these analyses are presented in Figure 27. Mean values for the St. Clair River sediments range from 10 to 44 mg/kg, with the lowest level again at station 2 and the highest at station 4. From the values in this figure, there is an apparent increase in nickel as the river descends from Lake Huron. This observation should be tempered with the fact that the nickel concentrations observed in sediments taken throughout the St. Clair River are within the range found naturally in unpolluted sediment of this type. This is equally true for the mean values observed at the head of the Detroit River (ranging from 24 to 32 mg/kg). Elsewhere in the Detroit River, stations along the United States shoreline show no appreciable enrichment over background except for stations 13 and 19, which average 142 and 66 mg/kg respectively. A lesser increase is apparent at stations 10, 12, 15 and 18, though the levels observed at these points are comparable to those of stations 3 and 4 in the St. Clair River.

Average sedimentary zinc concentrations are presented in Figure 28. In the case of zinc, a substantial enrichment is seen in downstream sediments of the St. Clair River over background levels of the upstream sediment. Mean values at stations 1 and 2 are 59 and 33 mg/kg, respectively, whereas those at stations 3 and 4 are 86 and 91 mg/kg, respectively. Mean concentrations at the head of the Detroit River vary between 44 and 81 mg/kg. Although this is a substantial gradient for samples from the same milepoint, values from 20 to 100 mg/kg are normally encountered in unpolluted deep-water glacial clays of the type found at this milepoint. Thus the possibility exists that the gradient may result from such natural causes as variation in particle type and size, rather than anthropogenic influxes of zinc. Mean concentrations along the Canadian shore, with the exception of stations 12 and 21, lie within the range observed at the head of the river. Station 12 shows significant enrichment in sedimentary zinc, as does station 1. Along the United States shoreline, a vast amount of zinc has found its way into the sediment at station 10. The mean concentration recorded here was 385 mg/kg. The situation is similar at station 13 where the average was 335 mg/kg. The zinc content drops somewhat at station 15, to an average of 97 mg/kg. However, the Lake Erie interface stations of 19 and 20, which receive the waters from along the United States shoreline, record average concentrations of 346 and 270 mg/kg, respectively. Such levels indicate very significant inputs of anthropogenic zinc.

Manganese in the sediment phase is of paritcular interest for its sorption ability when present as a hydrous metal oxide. Like iron, it plays an important role in retaining metals and nutrient species in the bottom sediments. Mean values for sedimentary manganese are presented in Figure 29. Sediments from the head of the St. Clair River average 190 to 380 mg/kg, while those at the downstream stations are somewhat higher at 430 and 580 mg/kg. Thus, as with aqueous manganese concentrations, there appears to be an increase in sedimentary manganese as the river descends from Lake Huron. Mean values at the head of the Detroit River range from 370 to 420 mg/kg - somewhat less than the lower stations in the St. Clair River. Canadian waters downstream in the Detroit River show little enrichment in sedimentary manganese to the Lake Erie interface. United States stations are generally higher than corresponding Canadian stations, though, with the exception of station 10, they do not show major changes in the sediment manganese loadings.

Because of its sorption characteristics, iron is one of the most important constituents in the sedimentary environment. Its role in regulating sediment exchange processes is well documented[19,20,21]. Primarily for this reason, iron was determined in all sediment samples taken during the August, November, and May surveys. Mean values for these analyses are presented in Figure 30. A review of this data indicates a net increase in sedimentary iron as the St. Clair River descends from Lake Huron. Mean concentrations recorded at stations 1 and 2 are 12,300 and 4,300 mg/kg respectively, while those at the downstream stations 3 and 4 are 16,900 and 19,100 mg/kg, respectively. Iron content of the sediment at the head of the Detroit River averages between 12,500 and 13,100 mg/kg - very close to that observed at station 1 in the St. Clair River. Elsewhere in the Detroit River sediments show appreciable variation, from a low of 7,800 mg/kg at station 14 to a high of 27,100 mg/kg at station 10. The highest mean concentrations found in the Detroit River occur along the United States shoreline, where other heavy metal enrichment was observed (stations 10, 13 and 19).

In addition to nutrient and heavy metal analysis an attempt was made to determine the chlorinated organic species present in the sediment samples collected during the three surveys. Due to the large background of other organic materials present in the majority of the river sediments, it was not possible to obtain satisfactory results with currently available analytical techniques.

Sediment Exchange ·

The sediment exchange studies were designed to investigate procedures for estimating the potential input of chemical constituents from the bottom sediments into the aqueous phase. The influence of such an input on the water quality of the river can be important in the formulation of a mathematical model of the river basin, and in projecting future water quality. Estimation of sediment exchange inputs, however, is difficult and at present can only be accomplished through empirical methods. Such ethods as reported Such methods as reported in the literature are widely divergent in terms of technique and are usually tailored to specialized simulations. Consequently, the procedures used during this study were varied and modified in an attempt to find a satisfactory compromise in simulating conditions which exist in the two river basins of concern.

The experimental systems used on sediments from the three field surveys have been described earlier. The only major change after the onset of the experiments was the substitution of "synthetic river water" for reagent water as the exchange medium for sediments obtained during the November and May surveys. This synthesized river water contained calcium hardness and carbonate alkalinity in concentrations closely approximating those found in the actual river water. This substitution had profound effects in the exchange levels of certain constituents.

The results of the exchange experiments are presented in the appended Tables A-12 through A-14. The parameters represented in this table include Chemical Oxygen Demand (COD), Kjeldahl nitrogen, nitrate-nitrogen, total phosphorus, cadmium, chromium, copper, iron, manganese, nickel, lead, and zinc.

Reviewing the data in Appendix Tables A-12 through A-14, the exchangable quantity of COD in the November and May sediments ranged from less than 0.1 percent to 2.49 percent. The use of adjusted-hardness water had apparently little effect on the exchangable COD. Kjeldahl-nitrogen, on the other hand, seemed to be substantially affected by the use of "synthetic river water". Values for the November and May sediments ranged from 1.0 to 6.1 percent, while those of the first experiment (August sediments) were much higher. The effect on nitrate-nitrogen was not so evident. While exchange values for the experiments using "synthetic river water" ranged from 0.21 to 27.2 percent, the values from the August samples were observed to fall both above and below this range. Total phosphorus exchange did not appear to be affected by the medium change. Values for the November and May sediments ranged from 0.21 to 4.58 percent, while those from August were generally in this same range. The affect of carbonate hardness was quite apparent on the exchange coefficients of five of the metals studied. Copper exchange in the "synthetic river water" ranged from 0.02 to 0.5 percent (November and May surveys), while values as high as 55.2 percent were observed with reagent water medium. Iron was exchanged at between 0.07 and 3.50 percent in experiments with the November and May sediments, while the August sediments exchanged to a much greater extent with the reagent water medium. The effect was very similar with manganese, which exchanged from 0.18 to 4.27 percent in the "synthetic river water". Nickel exchange values in the adjusted - hardness water ranged from 1.2 to 4.8 percent. Though insufficient analytical sensitivity was established for nickel during the first exchange experiment, the one value that is reported is much higher than the corresponding values from subsequent experiments in which the "synthetic river water" was used. Zinc, was most affected in the use of water with carbonate alkalinity. Whereas exchange waters during the first experiment reagent water leached from 10.4 to 97.4 percent of the total sedimentary zinc, the use of "synthetic river water" dropped the exchange efficiency into the 0.3 to 5.9 percent range. Cadmium, chromium, and lead exhibited only slight variations between exchange in the two media.

Discussion

Aqueous phase - In discussing the condition of the aqueous phases of the St. Clair and Detroit River systems, it is advantageous to deal with each of the rivers individually. The St. Clair River, being a narrow, deep, and rapid flowing body is distinctly different from the generally wider and lower velocity Detroit River.

The hydrology of the St. Clair River and the relative abundance and placement of industries along the river reflect themselves directly in the water quality of the river system. Data gathered during the present study indicate that dissolved oxygen, temperature and specific conductance are only slightly influenced by inputs to the river system. The velocity and turbulence in the river virtually preclude concentration gradients of any appreciable magnitude.

Some influence by pollutional inputs is seen in the area of oxygen demanding material (BOD and COD), though this influence is relatively small. Heavy metals in the aqueous phase of the St. Clair River are enriched at certain points, particularly stations 1 and 4, though the magnitude of the enrichment limits the physical significance of the inputs. The same holds true for chlorinated organic species.

The Detroit River system is rather a different case. The physical geography of this system is such that a large percentage of the shoreline is covered by residential and industrial development, thus the pollutional inputs to this river system are much greater in magnitude. This is compounded by the somewhat slower velocity and the presence of backwater areas. The result is that pollutional inputs have a significant effect on the water quality in the Detroit River.

Dissolved oxygen in the Detroit River shows much greater variation than in the St. Clair River, especially during the summer months when water temperature rises. At certain points in the river, particularly along the United States shore and downstream from the Rouge River, the dissolved oxygen concentrations dip to undesirable levels. At station 19, where the river velocity is drastically reduced, oxygen demanding materials further deplete the available DO.

The distribution of oxygen demanding materials in the Detorit River follows closely the distribution of heavy metals and other contaminants. Generally, the most polluted areas lie downstream from the Rouge River. From station 10 south to Lake Erie, the waters adjoining the United States shoreline are highly enriched in a wide variety of contaminants. Waters adjoining the Canadian shoreline at station 12 seem also to be carrying an appreciable pollutant burden - particularly mercury.

One very significant increase in the aqueous phase of both the St. Clair and the Detroit Rivers which was noted during the field surveys was total iron. The net increase through the combined St. Clair-Detroit River systems amounts to more than an order of magnitude. Where mean concentrations of less than 100 mg/l are present in the headwaters of the St. Clair River, waters entering Lake Erie from the Detroit River contain 830 to 2,300 mg/l, on the average. Such an enrichment is particularly significant because of the sorption potential of hydrous iron oxides for heavy metals and biostimulants such as phosphorus . In addition, there is some evidence that such a shift in aqueous iron concentrations can result in a shift in the dominant type of algae from greens to more undesirable blue-greens[25] .

Sediment Phase - As stated earlier, the intent of the sediment analysis program was to provide information on an important area of the river systems where only minor amounts of such information has been obtained to date. To this end, the surveys were quite successful. Nonetheless, results gathered during these surveys should be considered only the initial effort for an on-going study of the sediment phase in the Detroit River and the St. Clair River. The information gathered on sampling techniques, analytical techniques and treatment of sediment data has been appreciable and should serve as the basis for further study.

Sediment sampling, for example, was found to be difficult in sections of the two rivers where high velocity and greater depth were encountered. The use of a gravity-coring device for sampling had been chosen for its ability to recover relatively undisturbed sediment profiles. By comparison, a dredge sampler, such as the Ponar device, takes a sample with a high surface area to depth ratio and disturbs the sediment so that no sectioning of the sample by depth can be accurately accomplished. The samples taken with the corer from the Detroit and St. Clair River bottoms were recovered with the oxidized surface layer relatively intact. Sectioning of the cores to obtain the upper five centimeter layer of sediment for analysis was thus a fairly accurate process.

Some difficulty in obtaining core samples during the August 1973 survey was encountered with the original coring device. Despite the weight of the device (24.5 kg) the current in the St. Clair River and at the head of the Detroit River caused the coring tube to strike the bottom at an angle substantially different from the ideal 90° . The Ponar dredge sampler was used as a backup and thus many of the sediment samples gathered during this survey are dredge samples rather than cores. The coring device was subsequently modified by adding weights and a finned guidance section resulting in a total weight of 30 kg. The sediment retaining head was also changed to provide better capture in unconsolidated bottom materials. The resulting corer proved to be much more efficient during the two remaining surveys. Nonetheless, there were times when no representative bottom sample could be obtained either with the corer or the dredge sampler. If the river bottom was covered with relatively large stones or unconsolidated sand, neither device produced a satisfactory sample. Such limitations have been mentioned by other researchers [26].

In evaluating the trends of constitutents in the river bottoms, the lack of one or two of the three possible samples at a given station is a significant limitation. Mean values for the St. Clair River, for example, are often based on less than three determinations. Despite this limitation, some important conclusions can be drawn from the data gathered during this study. The St. Clair River does show enrichment in certain sedimentary constitutents (e.g. COD, Kj eldahl-nitrogen, total phosphorus, chromium, zinc, manganese and iron) as it descends from Lake Huron. In most instances, however, this increase is relatively small. The Detroit River sediments, on the other hand, show substantial enrichment in many parameters, though this occurs primarily along the United States shoreline. Stations 10, 13, 19, and 20 were found to be major zones of deposition for most of the constituents surveyed. Station 12, along the Canadian shoreline, showed somewhat the same characteristics, especially with respect to the toxic heavy metal, mercury.

Some corollary information on the mechanisms for retention of certain constituents in the sediment phase can be developed from the data generated in this phase of the study. Table 16 is a compilation of correlation analysis results between two hypothesized mechanisms for such retention and several constituents determined in the St. Clair and Detroit River bottom samples.

The higher the correlation coefficient, the stronger is the relationship between mechanism and constituent. For examples, the adsorption capacity of iron, present as the hydrous metal oxide, is very important in the scavenging and retention of cadmium and manganese. It appears to be somewhat less important for the remaining constitutents, though the relationship is significant for every constituent except mercury. Similarly, the chelation and sorption by organic species, represented in this correlation by COD, is very important with regard to cadmium, copper and zinc, and somewhat less so for all others, again with the exception of mercury. Three other major sediment components are thought to be of importance in retention and scavenging calcium carbonate, clay fraction and sulfide [19,20,21]. Since these materials were not determined in this study, they cannot be evaluated with the data presently available.

Sediment Exchange -

In the sediment exchange experiments carried out in this study, the most favorable conditions for release of sedimentary constitutents to the aqueous phase were utilized. This provided simulation of the "worst possible" condition for pollutional inputs from the sediments. In reality, such conditions do not exist, except when the aerobic-anaerobic interface in the sediments rises to, or above, the sediment-water interface. Under conditions usually found in the Great Lakes, dissolved oxygen is present in the waters immediately above the sediments at levels greater than 1 mg/l. This results in a superficial layer of oxidized sediment which serves as a barrier to the transport of sedimentary constituents into the aqueous phase. The migration of metals and nutrient species dissolved in the sedimentary interstitial liquid is halted at this barrier. At the same time, this layer serves as a scavenger of phosphates, metals and other species directly from the aqueous phase. As a consequence of this "semi-permeability", appreciable build-up of environmental pollutants in the surface layer is often observed, which in turn makes the stability of

Table 16. SEDIMENT CORRELATION MATRIX

Specie	n	Total Iron (r)	Chemical Oxygen Demand (r)
Cd	41	.810	.849
Cr	41	.592	.635
Cu	41	.755	.840
Fe	41	-	.753
Hg	26	.015	.125
Mn	41	.851	.526
Ni	41	.672	.690
Pb	41	.556	.622
Zn	41	.723	.812
Total Phosphorus	41	.616	.748

Minimum Significant Correlation

n	r (95%)	r (99%)
26	.470	.565
41	.373	.454

this trapping layer exceedingly important.

In relatively unpolluted waters, oxidized surface layer ranges in thickness from a few millimeters to 2 to 3 centimeters. The exact thickness varies, especially in areas where density-stratification occurs, according to the organic deposition to the sediments and the availability of oxygen in the waters immediately above the sediments. If there is depletion of oxygen in the hypolimnion, for example, or if the organic loadings to the sediments are substantial, the thickness of this oxidized layer will decrease until the aerobic-anaerobic interface rises to the sediment-water interface. At this point, relatively abrupt releases of reduced manganese and nitrogen forms (as well as phosphate, silicate, carbonate alkalinity and ferrous iron) result in significant changes in the quality of the overlying waters[20] . In some cases, an order of magnitude increase in the rate of phosphorus release to the water column has been observed[27] . These sediment derived solutes are then mixed throughout the overlying waters in a manner determined primarily by flow pattern and turbulence.

During recent summers, sediments in the central basin of Lake Erie have undergone the process described above as a result of dying plankton forming a strongly reducing layer on the bottom, two centimeters thick[27] . Even when excess dissolved oxygen is reintroduced, (for example, during overturn) recovery of the oxidized layer is slow and the barrier it provides remains unstable for sometime.

There are four major factors which regulate the depth of the aerobic-anaerobic interface and hence the exchange of sediment constituents into the aqeuous phase. They include: (a) turbulence; (b) oxygen demand; (c) texture of the sediment surface; and (d) dissolved oxygen in the overlying water. In the present study, an approximation was made for each of these factors which produced the most favorable conditions for sediment exchange. To accurately extrapolate the data generated in this study, further work is needed to determine exchange coefficients under conditions of higher oxygen content, lower turbulence, and with sediment water interfaces which more closely approximating those of the actual river bottoms.

BIOLOGY

Introduction

The assessment of the existing ecological status of an area can best be based upon the evaluation of data obtained by monitoring various biological communities. As the study of water quality becomes ecologically oriented, the question of the relationship between animal and plant communities and the chemical characteristics of the water must be explored. The classical response of organisms (if such a response exists) to their environment has been detailed frequently, beginning as far back as 1850, although one of the first practical applications was contained in the saprobian system of Kolkwitz and Marsson[28], which was based on a check list of organisms and their response to organic wastes.

The biological phase of the current study was directed at using to the greatest extent possible, the available historical records and data amassed on the biological characteristics of the interconnecting waterways in the study region as well as adjacent areas. Communities selected as important "on site" monitors of water quality within the area were the benthic macroinvertebrates and the phytoplankton.

The benthos are directly subjected to adverse conditions of existence as a result of their habitat requirements and their general inability to move great distances by self locomotion[29]. The varied responses of different taxa of benthos give accurate and valuable information on existing as well as indications of past conditions in a particular river section. As organisms that comprise the benthic communities respond differently than other taxa to environmental stress, the use of historical records of these responses is invaluable. Some species, due to niche specificity, cannot tolerate any appreciable water quality changes, whereas others can tolerate a wide range of conditions. In general terms, a natural, unpolluted system will support many different taxanomic groups and few individuals of each specie. In a polluted or otherwise altered area the converse is true, with many organisms of each of a few species being present. The benthic community was used both to complement historical records of the area and because of their intraspecific response to changes in environmental quality.

The phytoplankton community was considered to be important for all the aforementioned reasons, as well as the part they play in Lake Erie. The phytoplankton are, by nature, free floating and are therefore transported by currents both vertically and horizontally.

It is the horizontal disturbance, and more specifically the upstream-downstream relationships, that were of interest. By studying the changes in the phytoplankton community from the upstream areas through to Lake Erie it was hoped that the point at which bloom causing organisms began to become significant could be identified. Once this area was determined, the vector of pollution could be isolated and appropriate steps taken toward correction of the problem. In addition to this specific aim, the phytoplankton were studied to indicate present environmental quality. When the algal community is studied in its entirety, that group may give reliable information as to water quality[30].

Methodology

Field Sampling -

Station locations for benthic macroinvertebrate collections in the St. Clair and Detroit Rivers were chosen to be concomitant, where possible, with those locations sampled during the United States Public Health Service study of 1964[6] (Figure 34). Each of the 22 collection sites were sampled during the first survey (August 1973) to qualitatively determine if they were worthy of further quantitative evaluation. As this was the case with all sites selected, the quantitative benthic study was undertaken during the two subsequent surveys (November 1973, May 1974). Two samples were secured from each of the station sites to allow for gross similarity comparisons and increased statistical reliability.

A Ponar grab, Wildlife Supply Company (No. 1725), was chosen as the best method of securing benthic macroinvertebrate samples. Both the St. Clair and Detroit Rivers have, for the most part, comparatively hard substrates and high flows, making them amenable to application of the Ponar Grab sampler. The Ponar has an effective sampling area of 23 x 23 centimeters (0.0529 m^2) and weighs approximately 37 kg, as used in this study. Upon retrieval, all benthic samples were washed on board, using a Ponar wash frame (Wildco No. 188). This provides an efficient method for field washing - out of fines and silts, leaving all organisms and particles larger than 520 m. The prewashed samples were then transferred into one liter bottles containing freshwater, labeled and put aside for later fixing. Each sample was fixed at the end of the day with 70 percent ethyl alcohol or in the case of samples containing high percentages of annelid worms 45 percent formalin solution[35,36]. Macroinvertebrate animals were hand picked from all samples prior to identification, counting and cataloging.

Samples for phytoplankton analysis were taken from four areas of the Lake Huron - Lake

Figure 34 . Benthos sampling stations 1973-1974

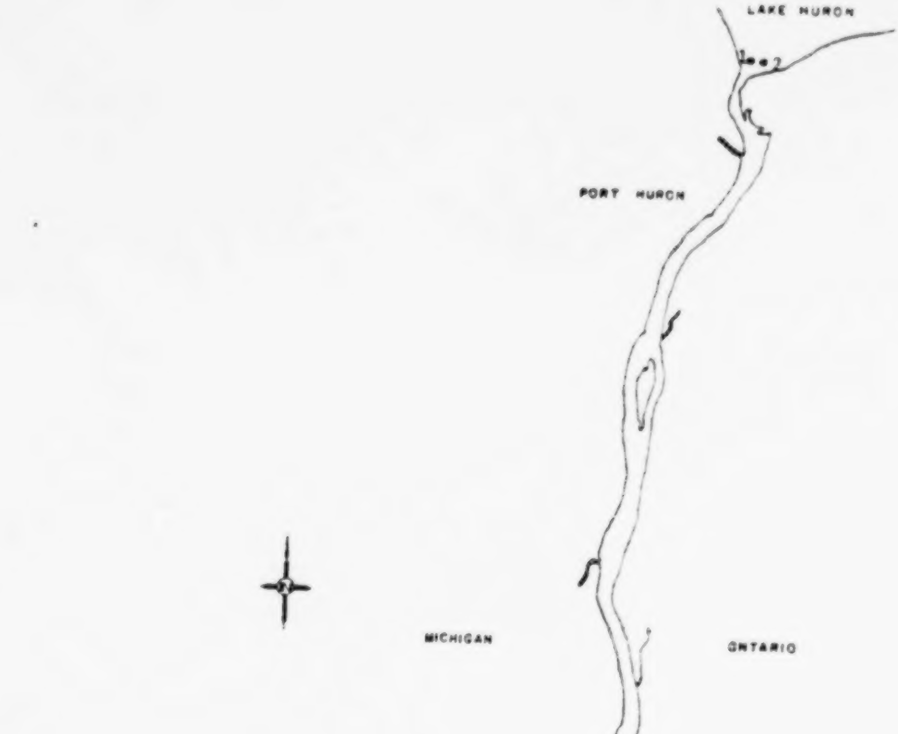

LAKE HURON
1
2
PORT HURON
MICHIGAN
ONTARIO
ANCHOR BAY
3
4
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST CLAIR

Figure 34 (cont.) Benthos sampling stations 1973-1974

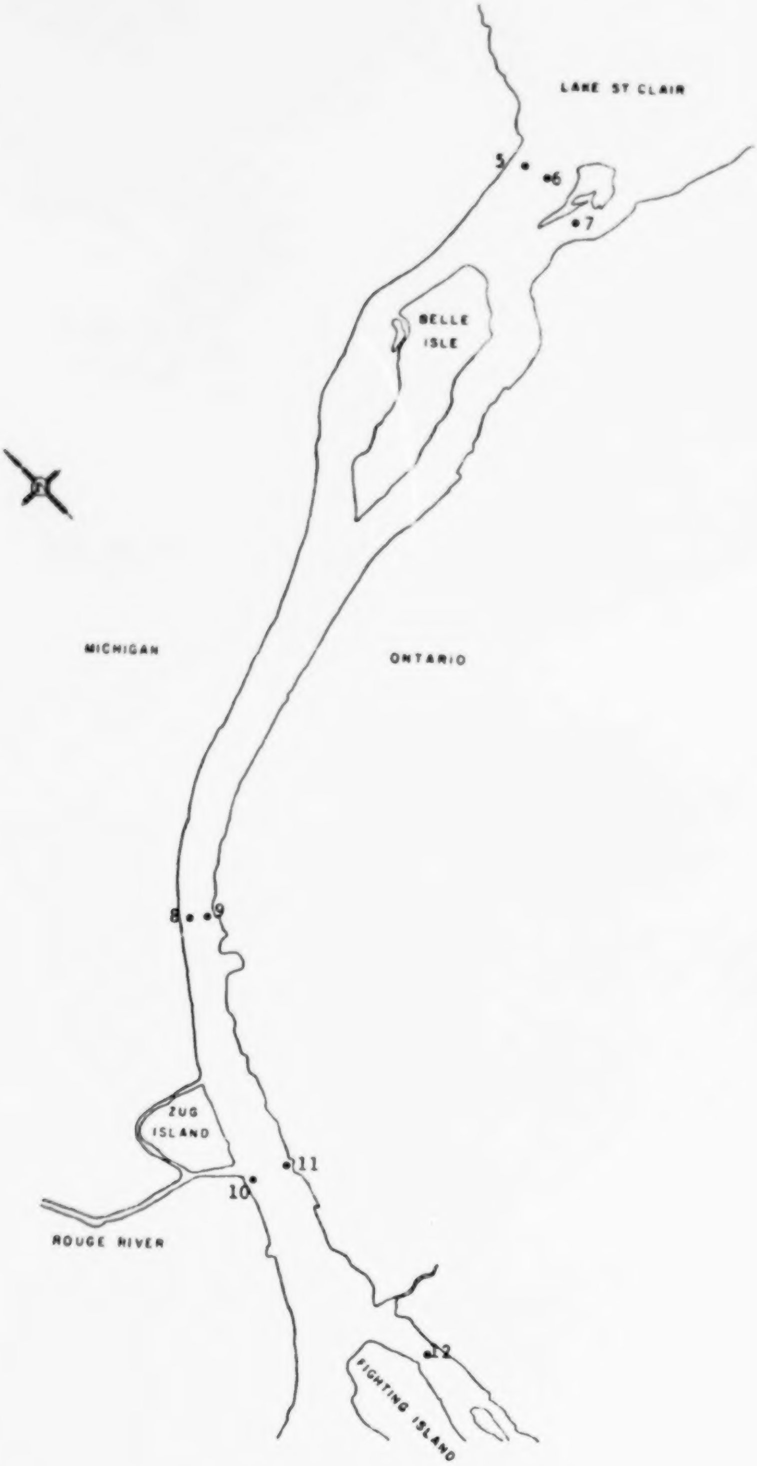
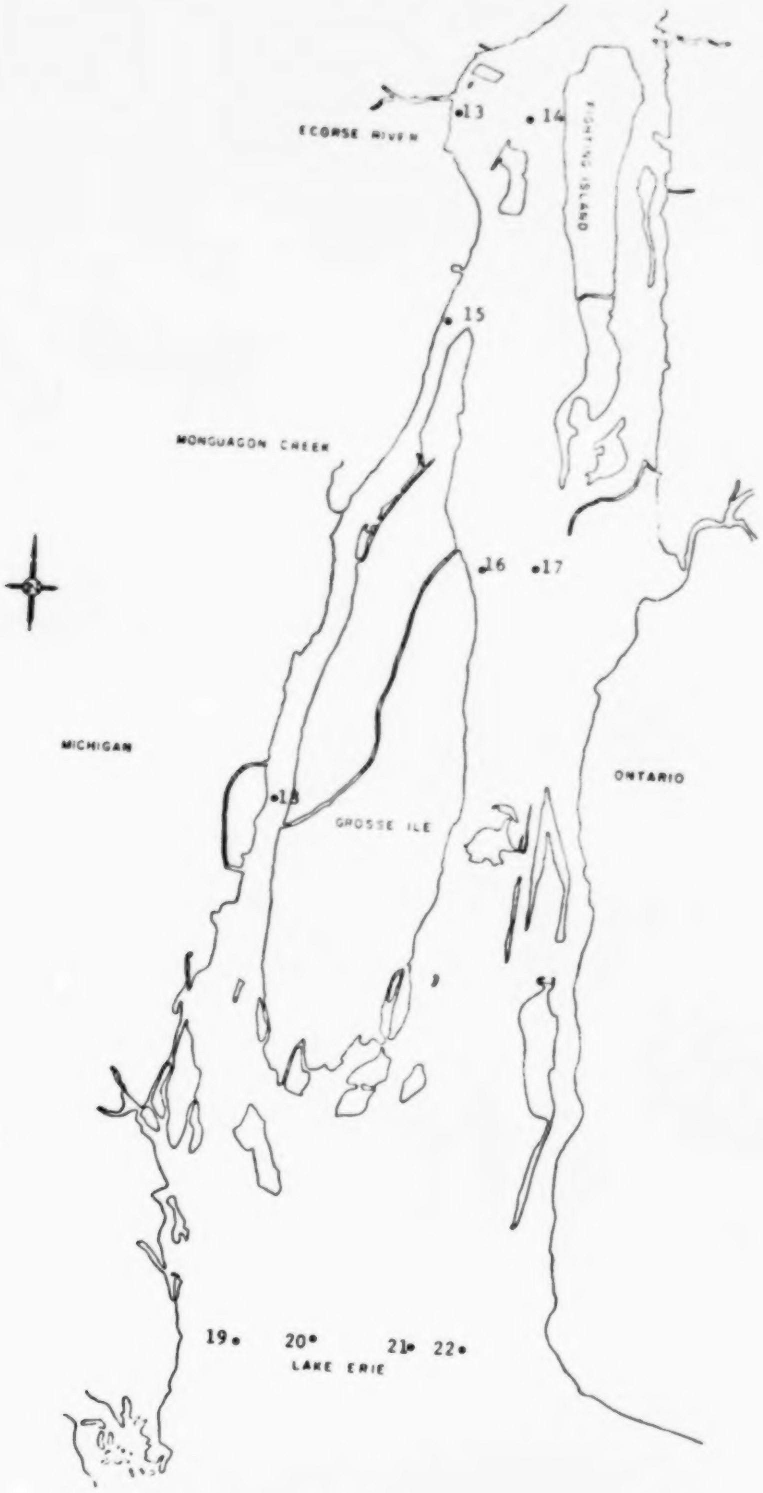

LAKE ST CLAIR
5
6
7
BELLE ISLE
MICHIGAN
ONTARIO
8
9
ZUG ISLAND
11
10
ROUGE RIVER
12
FIGHTING ISLAND

Figure 34 (cont.) Benthos sampling stations 1973-1974


13
14
ECORSE RIVER
FIGHTING ISLAND
15
MONGUAGON CREEK
16
17
MICHIGAN
ONTARIO
18
GROSSE ILE
19
20
21
22
LAKE ERIE

Erie connecting waters. These areas included: Stations 1 and 2 - St. Clair River at Lake Huron; stations 3 and 4 - St. Clair River in the vicinity of Algonac, Michigan; stations 5, 6, and 7 at Peach Island, mile mark 30.8, upper Detroit River; and stations 19, 20, 21, and 22, mile mark 3.9, lower Detroit River (Figure 34). A composite water sample composed of three (3) volumes of a horizontal type Van Dorn water sample bottle (2.1 liter volume), was obtained at each station. Samples were collected from subsurface (0.5 m), one-third depth, and near bottom (approximately 0.5 m above the bottom).

Replicate liter (1000 ml) subsamples were taken for pigment extraction and chlorophyll analysis. The subsamples for chlorophyll measurements were kept on ice and transferred to the laboratory for analysis. Replicate 250 ml subsamples were taken from each composite collection and preserved in Lugol's iodine solution until analysis was performed.

Analytical Procedures -

General - After the biological communities were sorted, counted, identified, and catalogued, various biomathematical indicies were applied to aid in the characterization of species associations and population similarities throughout the study region. Those indices directed at specific communities are discussed within the respective community subsections. The biomathematical expressions used to describe the taxanomic complexes of all communities studied are presented in the following paragraphs.

The expressions used to describe species richness at specific sites sampled during the three survey periods have been shown to correlate well with changes in water quality[37]. One formula is expressed as:

Richness = $S\text{-}1/\ln N$

where: $S=$ number of species

$N=$ total individuals Margalef[38]

$\ln=$ natural log

The second formula used was: Richness $d = S/\sqrt{N}$ Menhinick[39]

Richness (diversity) is lowest when the community is composed of many individuals of one species (diversity = 0)[40] . Diversity increases when limiting or inhibiting factors are removed; the species complex becomes more diverse and the community is referred to as being more stable. Such stability is the combined effect of several species undergoing minor but differing shifts in population numbers as a result of reproduction, mortality, and response to environmental factors[41].

The numerical assessment of population and community similarity was accomplished by applying Pirolot's or Sorenson's Similarity Coefficient[42,43]; this formula is:

$2\ c/a+b$

where: a = number of species in population "A"

b = number of species in population "B"

c = number of species common in both "A" and "B"

The calculated values indicate a percent similarity when multiplied by 100; the level of significance being chosen arbitrarily or statistically. Brown[43] indicates that researchers of benthic communities often use 0.60 (60 percent) as a level of significant similarity.

Perhaps the most accepted measurements of diversity are based on indices which are borrowed from information theory[44]. These measures of "informational diversity" are expressions of the degree of uncertainty involved in predicting the species identity of a randomly selected individual. The more diverse an assemblage, the more uncertain the prediction and, conversely, the less diverse, the more certain the prediction. The informational diversity of a collection is given by:

$\bar{d} = (n_1/N) \log_2 (n_1/N)$ Shannon's formula[44]

where: N = number of individuals of all species in the collection

n_1 = the number of individuals of each species

Although each biomathematical expression of community diversity, richness or similarity is extremely efficient and permits summarization of large amounts of information regarding numbers and kinds of organisms, it is essential to relate the derived numbers to each other, and to biomass determinations. In addition to this interrelationship, the macrohabitat requirement of species or groups of taxa were considered when discussing the biological communities present in the interconnecting waterways and possible environmental factors contributing to the specific biological development found to exist.

Benthos -

The previously picked benthic samples were transferred to a glass petri dish or Syracuse watch glass and hand sorted by gross taxonomic characteristics. Groups of taxa were then placed under a Bausch and Lomb variable zoom (10X - 70X) microscope for identification and enumeration. Taxanomic keys used were Pennak[35], Usinger[44], Needham and Needham[46], Leonard and Leonard[47], Burks[48], Edmondson[49], Hamilton et al[50], Hiltunen[36], Johannsen[51], Klemm[52]. The taxanomic data was then applied to various indices of species richness and expressions of faunal similarity and diversity described earlier.

Various analytical procedures specific to the benthic population were biomass (wet weight), subsampling, and clearing of the annelid worms for identification. The macroinvertebrate biomass determinations were made on a Mettler Type H-6 analtyical balance. The biomass determinations were made on the entire sample following removal of all external preservative by blotting on filter paper for one minute. The cases of caddis flies (Trichoptera) were excluded but shells of mollusks and crustaceans were included in biomass wet weights. The calculation used for wet weight of benthic invertebrates (g/m^2) was:

$$\frac{\text{wet weight of organisms in all samples (g)}}{\text{area of sampler (m}^2\text{)} \times \text{number of samples}}$$

Some benthic samples, notably those from stations 13 and 14, contained such large numbers of small organisms (annelid worms) that it was impractical to pick or count them all. In these samples the larger organisms and bits of detritus were removed by hand picking. The remaining sample was made up to definite volume and aerated and agitated to a homogenous mix. While the sample was thoroughly mixed a subsample of twenty five percent of the original volume was removed by a dipper. This aliquot was then treated as described above for identification. The total number of organisms per sample was then obtained by multiplying the number in the subsample by the aliquot percentage.

Representative oligochaeta were cleared prior to mounting to enable visual observation of the identifying characters employed in Hiltunen's[36] taxonomic key. Suspension of the organisms for several days (three to five) in Amman's lactophenol was found to be the best method of clearing. Amman's lactophenol is comprised of 100 g phenol, 100 ml lactic acid, 200 ml glycerine and 100 ml distilled water.

Phytoplankton - The subsamples for chlorophyll measurements were first filtered through Whatman, Type GF/C, glass fiber paper. Analytical techniques were similar to those spectrophotometric methods described by Slack, et al[53]. Filtered samples were tissue ground in 90 percent aqueous acetone and $MgCO_3$, centrifuged, and absorbance of the centrifugate read at wavelengths of 750 nm, 663 nm, 645 nm and 630 nm on a Varian Techtron, Model 635 spectrophotometer. Chlorophyll a was quantified from the following formulas:

$$\text{chlorophyll } \underline{a}\ (\mu\text{ g/ml}) = 11.64e_{663} - 2.16e_{645} + 0.10e_{630}$$

$$\text{chlorophyll } \underline{a}\ (\mu\text{ g/ml}) = \frac{\text{derived value } (\mu\text{g/ml}) \times \text{extract volume (ml)}}{\text{volume collected (1)}}$$

Before completing these calculations a turbidity correction was made by subtracting the 750 nm reading from each absorbance. Data is presented as mean chlorophyll a (g/l) at each station, compared with other stations, and correlated with mean total numbers of phytoplankton (no./l).

Replicate 250 ml subsamples were taken from each composite collection, preserved in Lugol's iodine solution, and taken to the laboratory for species identification and enumeration. After shaking, a ten milliter aliquot was removed from each subsample, placed in a counting chamber, permitted to settle for a period of not less than ten hours, and examined on a Wild, Model M-40, (400X magnification) inverted lens microscope. From these replicate samples a composite species list of phytoplankton was constructed expressing the occurrence of individuals as mean numbers/ml. These data were compared through the use of species richness indices, Shannon-Weaver diversity, and population similarity as discussed earlier.

Results

Benthos

St. Clair River - The benthic macroinvertebrate assemblage of the St. Clair River is strikingly homogenous, see Figure 35, Appendix B-1, and B-2. Only one genus was collected during the May and November sampling runs at the upstream stations (1 and 2); the North American prosobranch *Goniobasis* sp. Stations 3 and 4 were also dominated by *Goniobasis*, although the appearance of the lighter Trichoptera such as *Hydrophyschae*, *Cheumatopsychae*, *Macronemum*, *Brachycentrus* and *Athripsodes* was documened, see Appendix B-1 and B-2. Biomass calculations (grams/meter^2) for the four stations on the St. Clair River, averaged 20.92 and 31.60 for the November and May surveys respectively; this represents a two percent decrease from November to May. Following is the mean biomass of macroinvertebrates at the four stations in the St. Clair River:

Station	$\overline{X}$ Biomass	
	November	May
1	11.50	4.30
2	62.00	58.10
3	19.28	12.00
4	-	52.00
$\overline{X}$	30.92	31.60

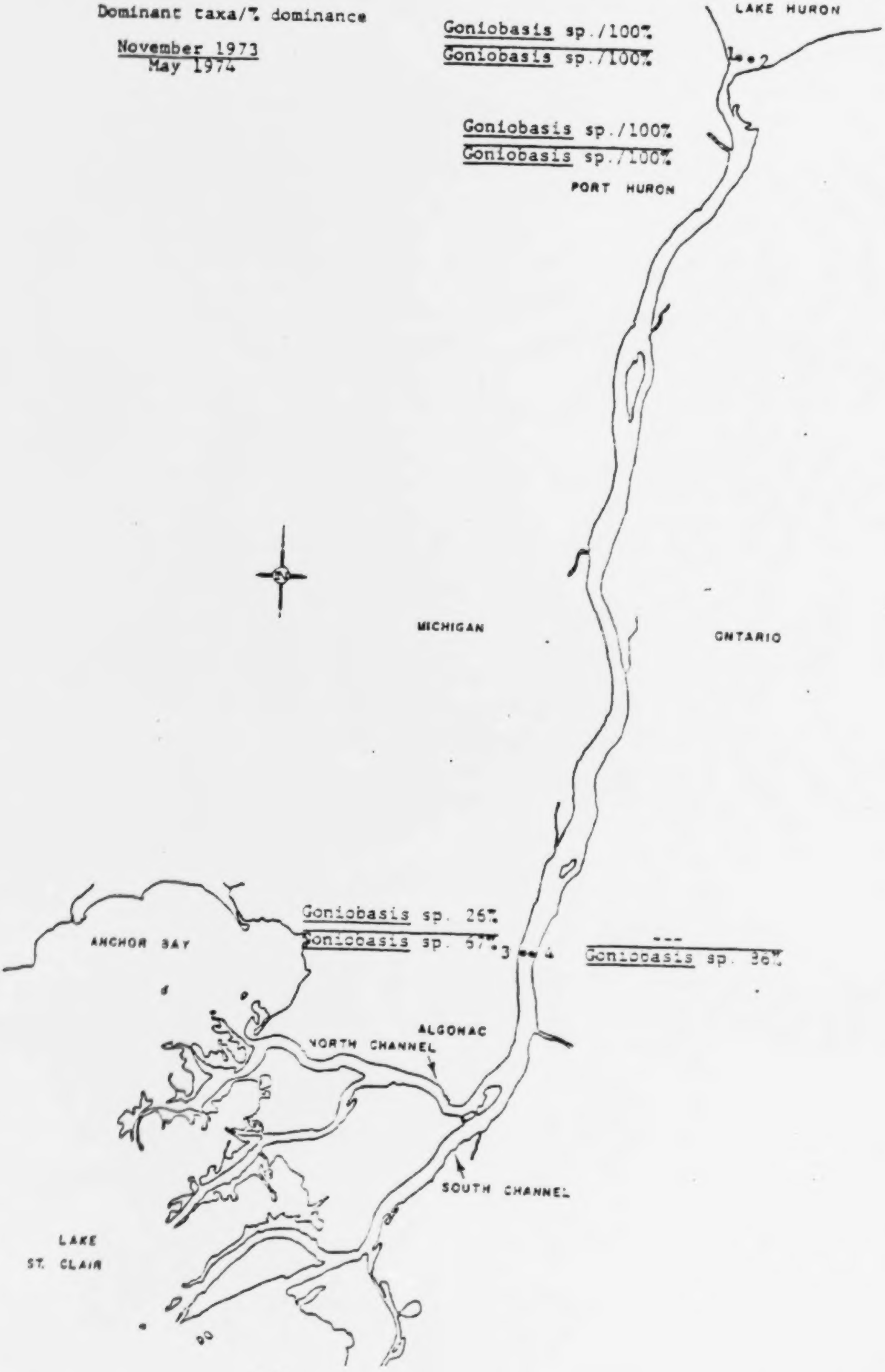
The May survey yielded an average of 45 percent fewer organisms (total numbers) than the same stations sampled in November 1973.

The diversity and richness calculations applied to the benthic community sampled in the St. Clair River generated real numbers only through the Menhinick formula ($S/\sqrt{N}$), Table 17. The population density was low at both the upstream and downstream transect; although much lower upstream (165 versus 302 individuals per meter^2) during the May 1974 survey.

From these data the St. Clair River demonstrated an undiversified macroinvertebrate community consisting of organisms indigenous to, and adapted for, rapidly flowing water with hard underlying substrates[54,55,41].

Detroit River - The Detroit River demonstrated a narrow range of benthic taxa and average numbers of genera during both the May and November survey dates. The average number

Figure 35. Dominant taxa Detroit and St. Clair Rivers


Dominant taxa/% dominance
November 1973
May 1974
Goniobasis sp./100%
Goniobasis sp./100%
LAKE HURON
1
2
Goniobasis sp./100%
Goniobasis sp./100%
PORT HURON
MICHIGAN
ONTARIO
Goniobasis sp. 26%
Goniobasis sp. 67%
3
4

Goniobasis sp. 36%
ANCHOR BAY
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 35 (cont.). Dominant taxa Detroit and St. Clair Rivers

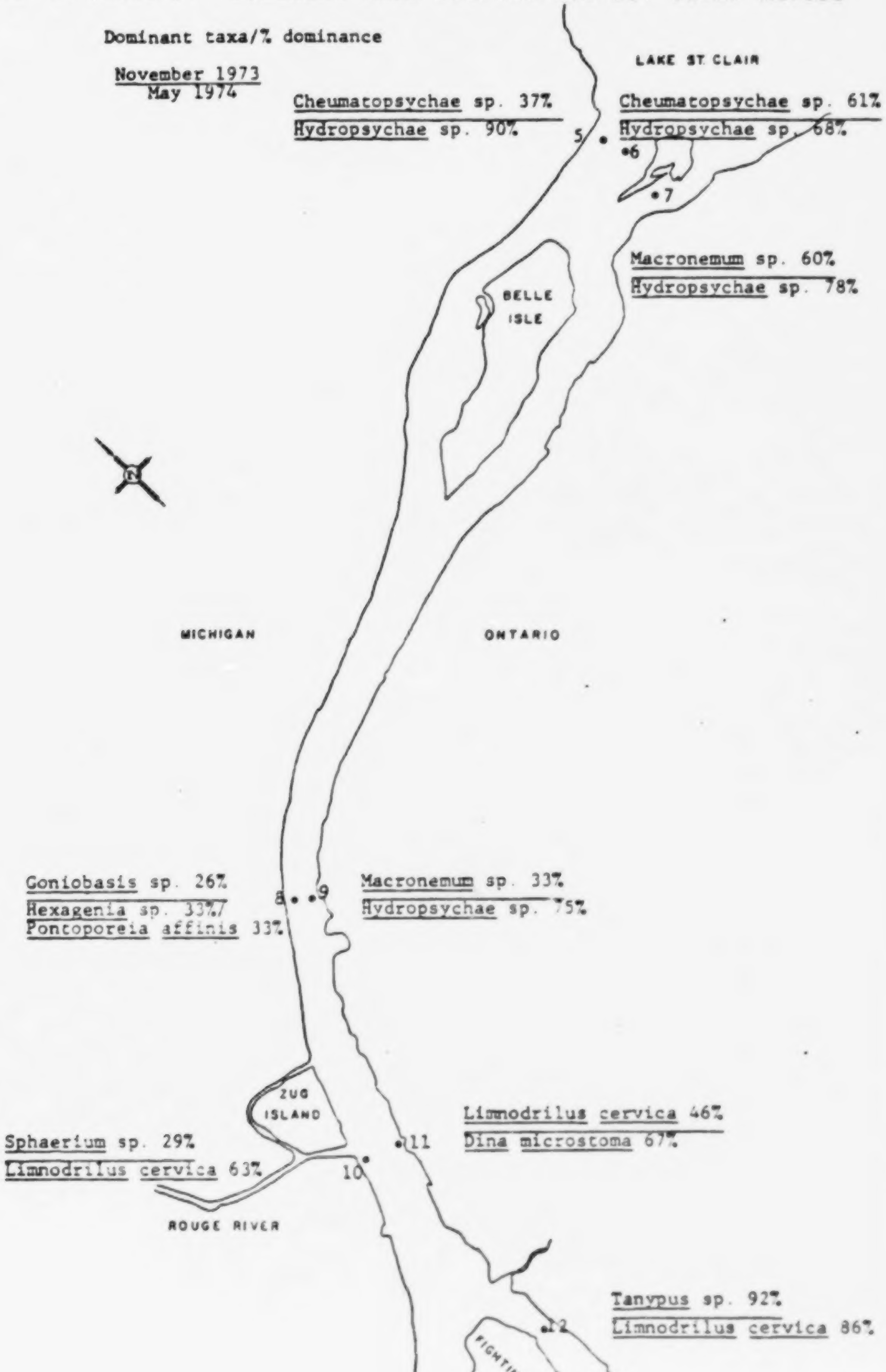
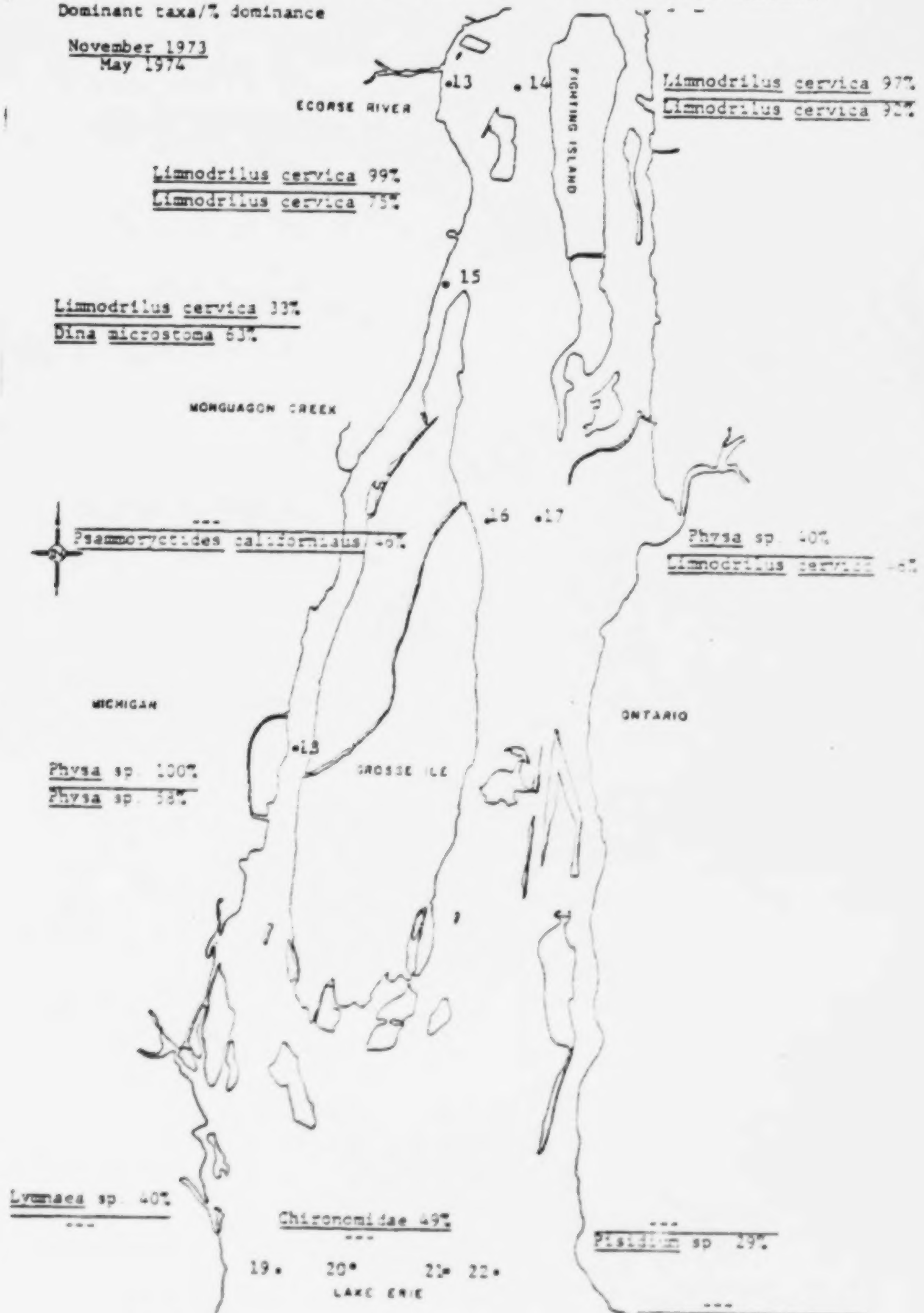

Dominant taxa/% dominance
November 1973
May 1974
LAKE ST CLAIR
Cheumatopsychae sp. 37%
Hydropsychae sp. 90%
Cheumatopsychae sp. 61%
Hydropsychae sp. 68%
5
6
7
Macronemum sp. 60%
Hydropsychae sp. 78%
BELLE ISLE
MICHIGAN
ONTARIO
Goniobasis sp. 26%
Hexagenia sp. 33%/
Pontoporeia affinis 33%
8
9
Macronemum sp. 33%
Hydropsychae sp. 75%
ZUG ISLAND
Limnodrilus cervica 46%
Dina microstoma 67%
11
Sphaerium sp. 29%
Limnodrilus cervica 63%
10
ROUGE RIVER
Tanypus sp. 92%
Limnodrilus cervica 86%
12
FIGHTING ISLAND

Figure 35 (cont.). Dominant taxa Detroit and St. Clair Rivers


Dominant taxa/% dominance
November 1973
May 1974
ECORSE RIVER
FIGHTING ISLAND
.13
.14
Limnodrilus cervica 97%
Limnodrilus cervica 92%
Limnodrilus cervica 99%
Limnodrilus cervica 75%
.15
Limnodrilus cervica 33%
Dina microstoma 63%
MONGUAGON CREEK
.16
.17

Psammoryctides californiaus 46%
Physa sp. 40%
Limnodrilus cervica 46%
MICHIGAN
ONTARIO
.18
GROSSE ILE
Physa sp. 100%
Physa sp. 58%
Lymnaea sp. 40%

Chironomidae 49%

Pisidium sp. 29%
19.
20.
21.
22.
LAKE ERIE

Sphaerium 50%
Pisidium 50%

Table 17. MENHENICK FORMULA CALCULATIONS - ST. CLAIR RIVER BENTHOS

November Station	1	2	3
$\bar{X}$ Biomass/m^2 (wet weight)	11.5	62.00	19.28
$\bar{X}$ Individuals/m^2	66	359	217
Shannon Weaver Diversity ($\bar{X}$)	0.00	0.00	1.39
Richness ($\bar{X}$) (S-1/lnN)	0.00	0.00	1.65
Richness ($\bar{X}$) (S/ N)	0.50	0.22	1.49

May Station	1	2	3	4
$\bar{X}$ Biomass/m^2 (wet weight)	4.30	58.10	12.00	52.00
$\bar{X}$ Individuals/m^2	28	302	113	491
Shannon Weaver Diversity ($\bar{X}$)	0.00	0.00	0.71	0.44
Richness ($\bar{X}$) (S-1/lnN)	0.00	0.00	0.84	0.47
Richness ($\bar{X}$) (S/ N)	0.85	0.27	1.03	0.50

of genera collected at various transects, grouped with references to location on the river, were: six for the "upstream" area, four in the "middle" region, and three in the "mouth" area. The upstream area was represented by stations 5, 6 and 7 in the vicinity of Peach Island: the middle area was delineated by stations 8-15 and encompassed the area from the Detroit Harbor Terminals, Incorporated to the northwestern tip of Grosse Ile (approximately 8.6 river miles) near the Trenton Channel, while the mouth area was considered as stations 16-22; Figure 34. The Canadian side of the river had one more genus than the American side, considering the average for all samples of both quantitative surveys; five genera versus four genera respectively. Important also are the kinds of taxa found to be indigenous to the analogous Canadian and United States stations. Stations 5 and 8 located in United States waters produced primarily Amphipoda, Gastropoda and Ephemeroptera, while corresponding Canadian sample sites (7 and 9) were dominated by Trichoptera and Gastropoda. The downstream points sampled in the vicinity of Mud Island on the United States side (stations 10, 13, 14) yielded Gastropoda, Sphaeriidae, and an overwhelming population of Annelid worms. Samples from Canadian waters (stations 12, 16, 17, 21, and 22) along the same reach produced Amphipoda, Ephemeroptera, Chironominae, and some Tubidificidae (annelid worms). The "mouth" area stations (15, 18, 19, and 20) located on the United States side consisted of Gastropoda, Hirundinea, Tubificidae and Chironomidae. Most generally, the United States waters were observed to have a benthic population most often associated with areas of low water quality[54,55,41,8].

The population density figures (Figure 36) for the Detroit River vary greatly with the region in question. The upstream transect adjacent to Peach Island demonstrates close replication between the two shoreline stations (numbers 5 and 7), while the sample located in the shipping channel (station 6) had a lower population density than the near shore stations on the November quantititative benthos survey. The higher numbers of benthic animals during the November survey at stations 5 and 7 decreased drastically in the sampling during May 1974; from 1947 to 198 individuals per square meter for station 5, and 2665 to 170 individuals per square meter for station 7, a 90 percent and 94 percent reduction, respectively. Station number 6 had an increase of benthic animals during the six months intervening, from 217 to 388 animals per square meter, representing a 44 percent increase. The taxa collected were very similar during both the November 1973 and May 1974 sample runs, consisting primarily of Trichopterans of the family Hydropsychidae at all stations. Population density followed much the same trend of decreasing numbers of organisms at stations 8, 9 and 11, although the total number of animals recovered was less than the initial river influent stations. The area sampled just below the Detroit River - Rouge River confluence showed the converse community seasonal variation, that is, the two samples had an increase of approximately 42 percent from November to May (993 to 1701 individuals/m^2). Station 12, located between Fighting Island and the Canadian

Figure 36. Benthos St. Clair/Detroit Rivers

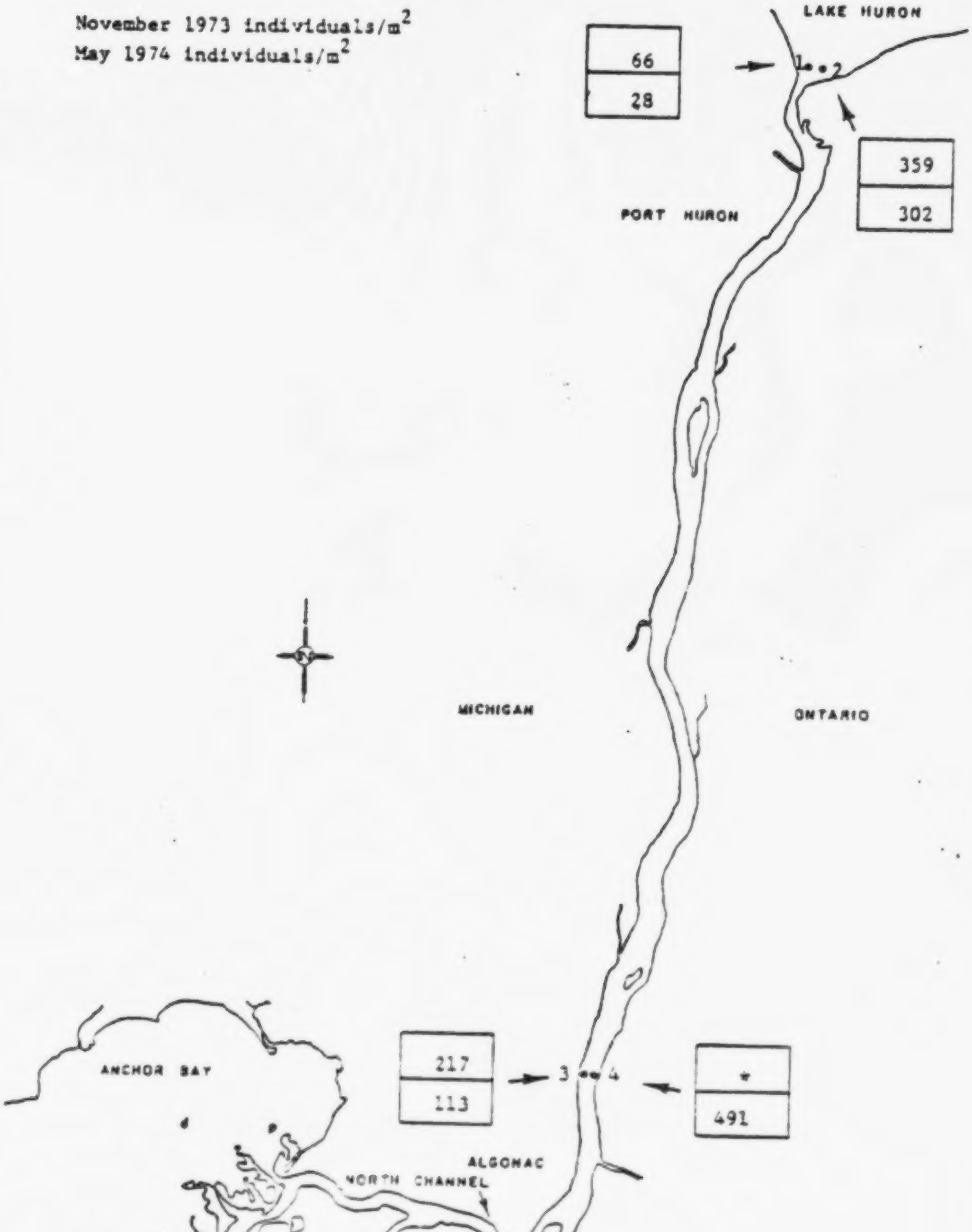

November 1973 individuals/m^2
May 1974 individuals/m^2
LAKE HURON
66
28
1
2
359
302
PORT HURON
MICHIGAN
ONTARIO
217
113
3
4
*
491
ANCHOR BAY
ALGONAC
NORTH CHANNEL
SOUTH CHANNEL
LAKE
ST. CLAIR

Figure 36 (cont.). Benthos St. Clair/Detroit Rivers

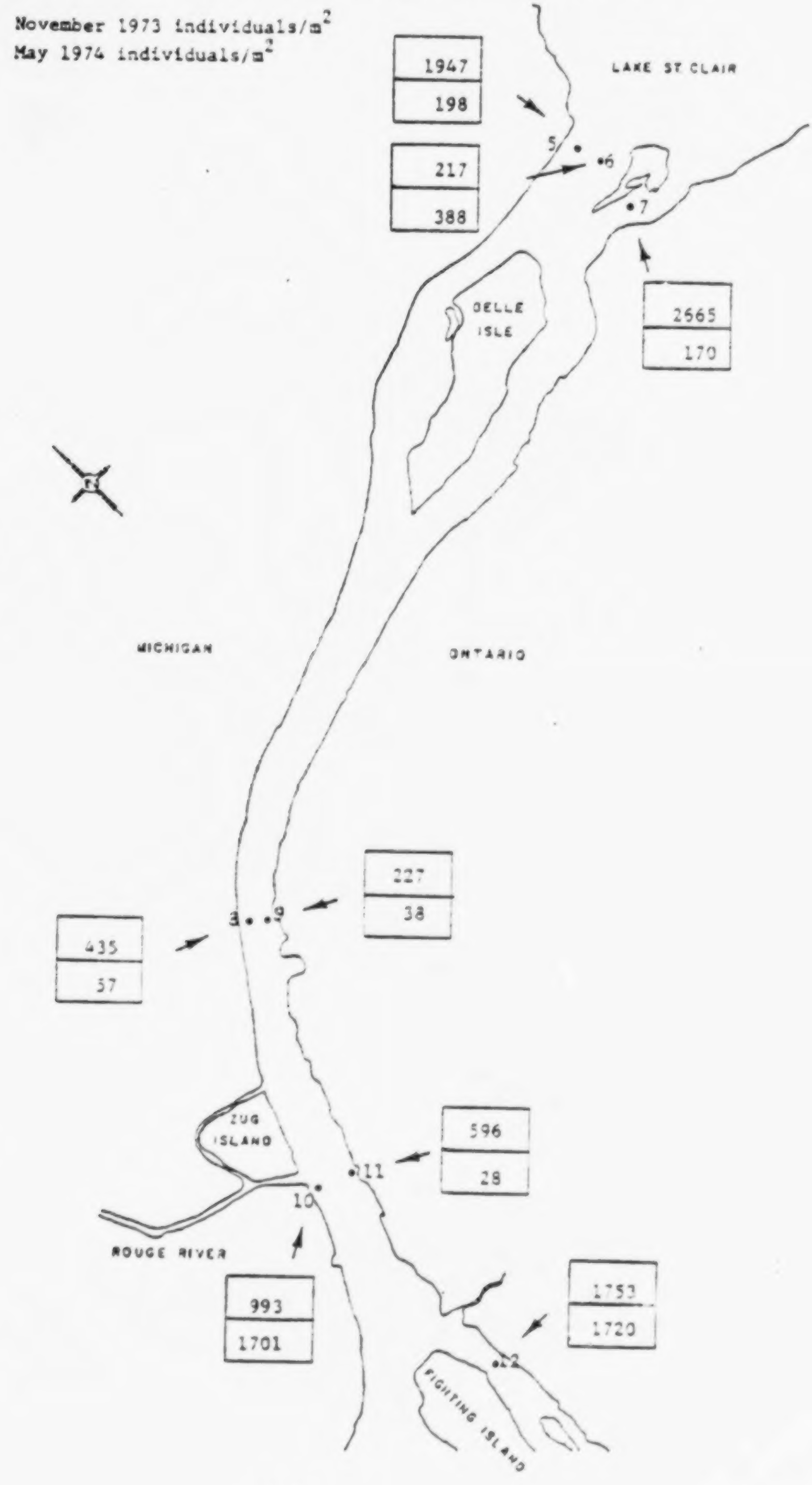
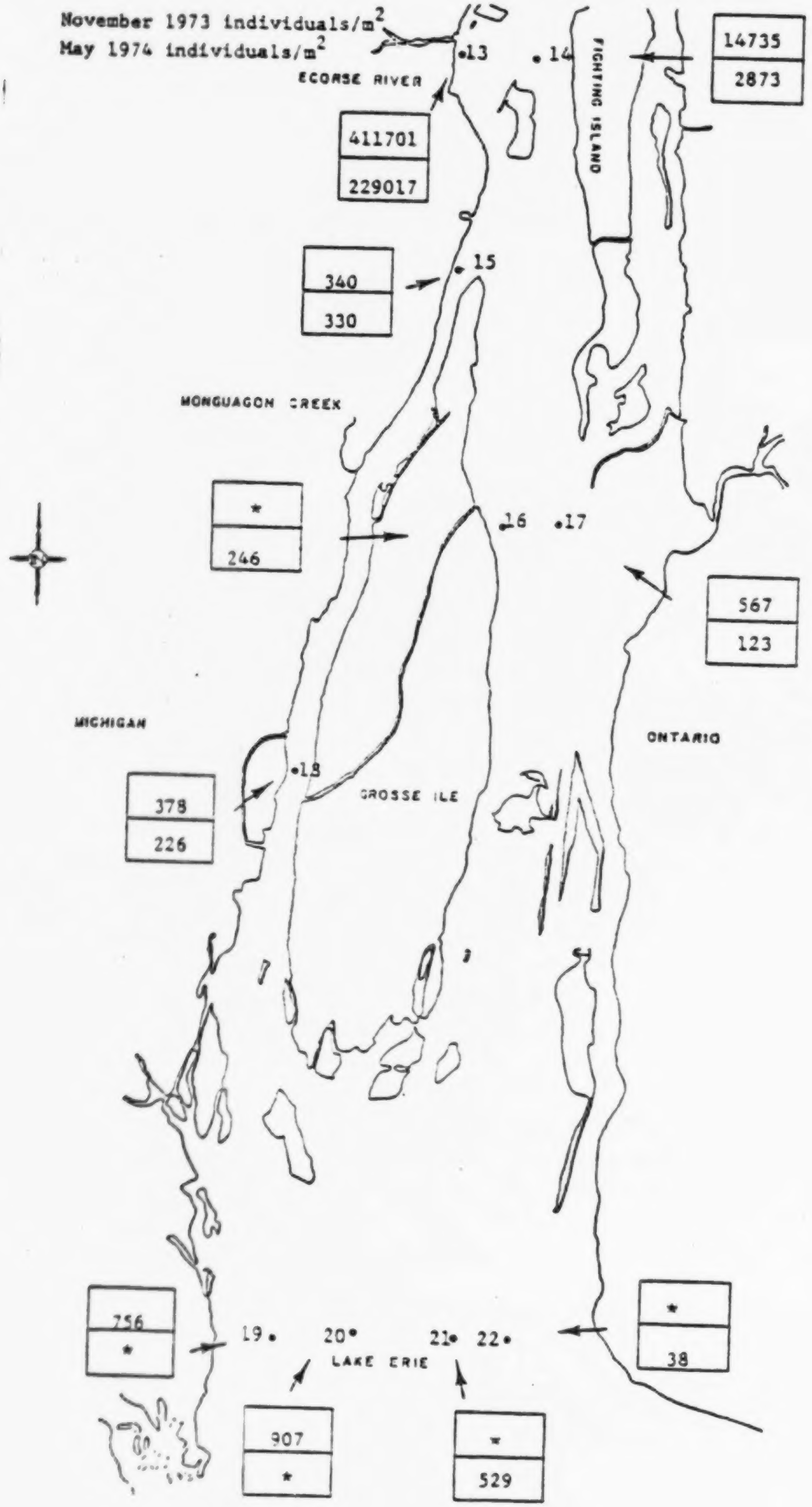

November 1973 individuals/m^2
May 1974 individuals/m^2
LAKE ST CLAIR
1947
198
5
6
217
388
7
2665
170
BELLE ISLE
MICHIGAN
ONTARIO
227
38
8
9
435
57
ZUG ISLAND
596
28
11
10
ROUGE RIVER
993
1701
1753
1720
12
FIGHTING ISLAND

Figure 36 (cont.). Benthos St. Clair/Detroit Rivers


November 1973 individuals/m²
May 1974 individuals/m²
ECORSE RIVER
FIGHTING ISLAND
MONGUAGON CREEK
MICHIGAN
ONTARIO
GROSSE ILE
LAKE ERIE
13
14
15
16
17
18
19
20
21
22
14735
2873
411701
229017
340
330
*
246
567
123
378
226
756
*
907
*
*
529
*
38

shore near LaSalle, Ontario, produced similar population densities on both surveys (1753 and 1720 animals/m^2). The November survey generated primarily Chironomidae of the genus Tenypus (Meigen), while the May samples were dominated by the annelid worm Limnodrilus cervix. The substrates collected at stations 13 and 14 were populated by extremely large numbers of Tubificidae, 411, 701 and 229,017 individuals per square meter at station 13 for the November and May surveys, respectively. Station 14 had lower, although still inordinately high populations of Tubificidae, numbering 14,735 and 2,873 animals per square meter for the November and May surveys, respectively. Limnodrilus cervix and L. angustipenis were the dominant forms (Figure 35). The next four river miles (12.0 - 8.0) were characterized by relatively constant population densities and benthic community development. The transect consisting of sample stations 19-22 (river mile 3.9) was predominated by Gastropoda such as Lymnaea, Physa, and Valvata sp. in November while Hexagenia sp. dominated in the May collections. Population densities ranged from 38 individuals per square meter for station 22 in May to 907 per square meter for station 20 in November. See Figure 35 for a composite of dominant taxa collected at the various stations.

The species richness ($S/\sqrt{N}$ and S-1/lnN) of the northern most transect in the Detroit River shows a high degree of similarity for both near-shore communities, and each indicate a diverse benthic population. With respect to station 6 richness, November samples had a lower diversity in the channel than comparable near-shore samples, however in May the biomathematically derived figures showed that all transect stations to be close in community richness. Station 8 had a higher species richness than station 9 on both sampling dates, although both stations 8 and 9 showed an increased richness of taxa as compared to the upstream stations in all but one sample; the May sample at station 9. This was due to the recovery of only one taxa of the Hydropsychidae, see Appendix B-1 and B2. Subsequent November samples indicate species richness values ranging from 1.37 at station 15 to 0.02 at station 13 where an average of the replicate samples produced 21,779 individuals per square meter represented by only three taxa. The May data produced values ranging from 1.50 at station 21 to 0.06 again at station 13 (12,115 individuals per square meter represented by six taxa).

The Shannon-Weaver ($\bar{d}$) diversity (informational theory) was calculated on all samples although only selected transects point up interesting biological responses in the Detroit River benthic faunal assemblage, Figures 37 and 38. These transects are delineated by stations 5, 6, and 7 at Peach Island (river mile 30.8); 10 and 11 just below the confluence of the Rouge and Detroit Rivers (river mile 19.0); 13 and 14 between Mud Island and Grassy Island (river mile 14.6), station 15 in Trenton Channel (river mile 12.0W), and

Figure 37. Shannon-Weaver diversity - November 1973 Benthos

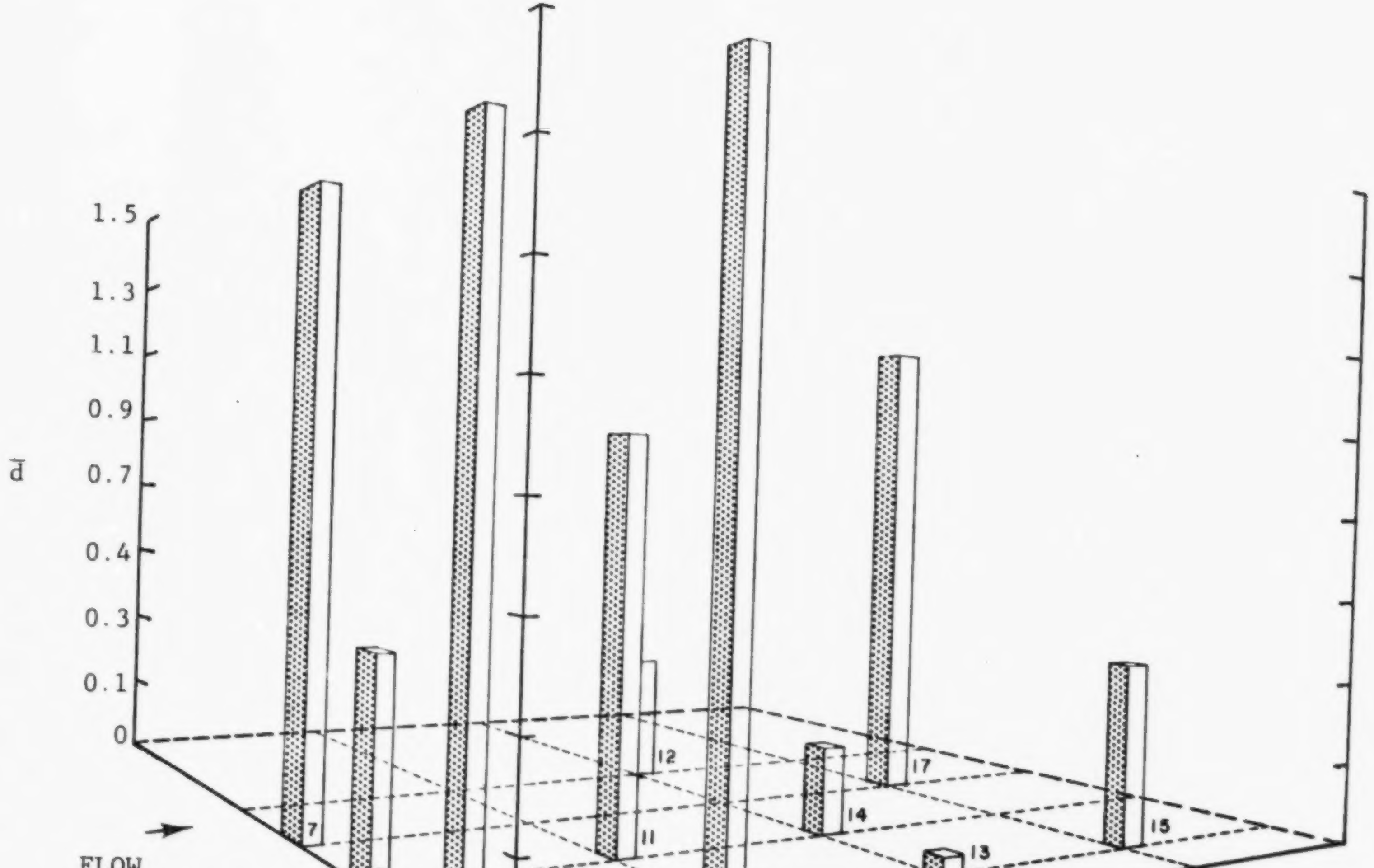
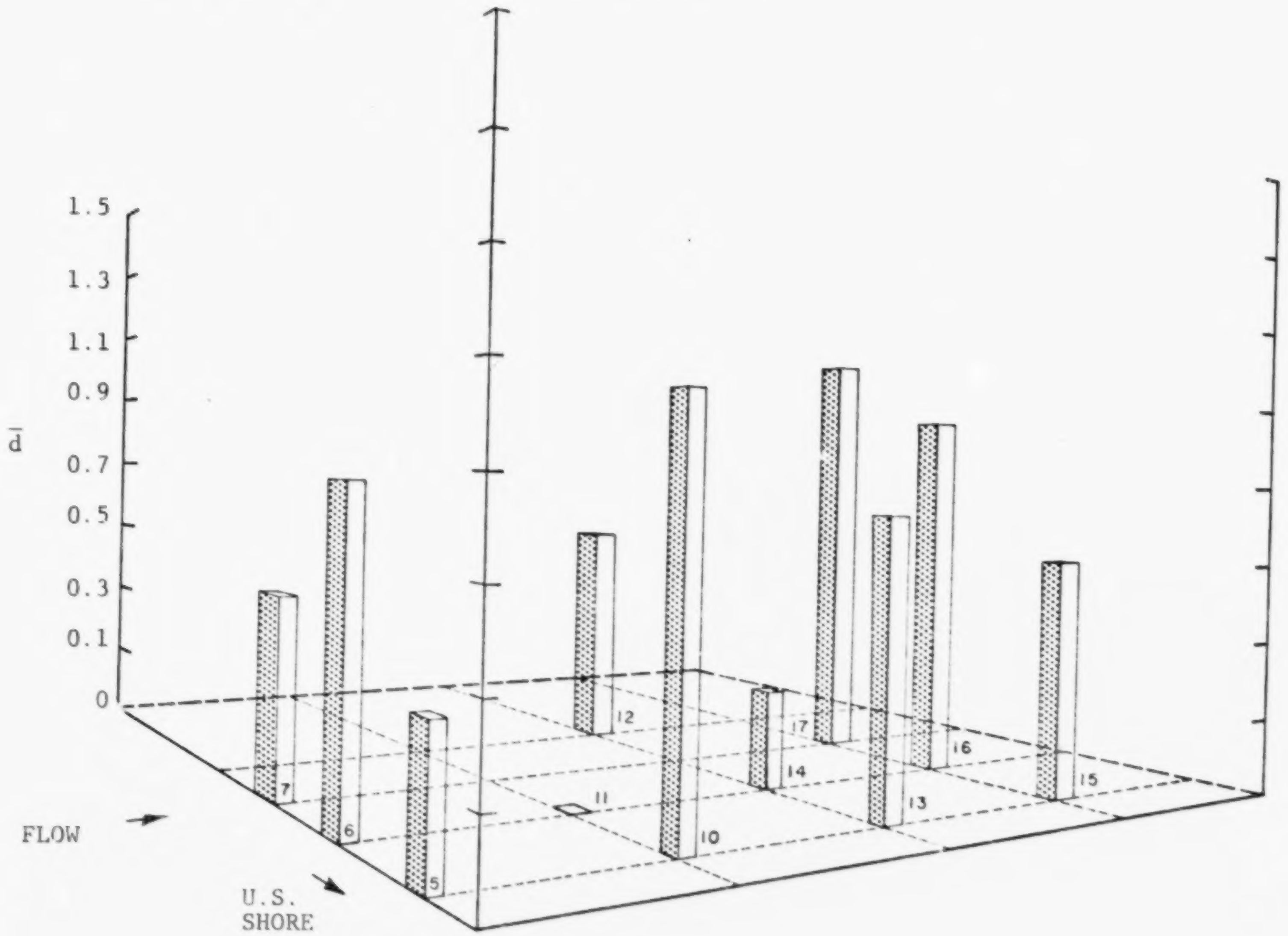


Figure 38. Shannon-Weaver diversity - May 1973



stations 16 and 17 just east of Grosse Ile in the Fighting Island Channel (river mile 9.3). The diversity of a particular community is best understood when it is related to biomass figures derived from that community[56], Table 18. At the initial transect, November diveristy calculations show station 6 to have both the lowest diversity, 0.50, and lowest mass of animals recovered (1.04 grams/m^2) while the near shore, and thus more protected, station 5 yielded biomass numbers of 6.62 grams per square meter and 20.04 grams per square meter, respectively. The diversity of each community was 1.47. From this one would expect the animals at station 7 to be more robust than those at station 5, assuming either the same taxa were taken at each location or that heavier forms were represented in the sample if different taxa were recovered, or both. In this case, both assumptions were observed to hold true. Station 7 was represented by several Pleurocerid Gastropods, a relatively heavy organism, while station 5 had only one individual of this taxa. The May collection of this transect pointed up the seasonal fluctuation of macrofaunal benthos in the Detroit River. The channel location (station 6) reported a higher diversity (0.77) and biomass (11.15 g/m^2) than either near shore station. The presence of the cold water stenotherm, Pontoporeia affinis (Lindstrom), was also first noticed at station 6 during this survey.

The two locations sampled below the mouth of the Rouge River indicated very high diversities in November (1.64 for station 10 and 0.92 for station 11) while they were lowered to 0.97 and 0.00, respectively, in the May collection. Benthic biomas was also greatly reduced between November and May. Station 10 had the highest on each sampling date with values of 31.10 in November and 9.44 individuals per square meter in May, while station II had values of 1.66 and 0.86 in November and May, respectively. Stations 13 and 14 had an extremely low diversity of benthic forms while the biomass was high. The indications of an organically enriched substrate in the vicinity of Mud Island are unquestionable with biomass numbers of 133.70 and 66.85 grams per square meter. The stations near Grosse Ile (15, 16, and 17) show a general increase in the diversity from the upstream stations of 12, 13, and 14, while the biomass decreases. Station 15 shows the lowest diversity and highest biomass of these three stations however and is therefore considered to be somewhat lower in overall quality to 16 and 17. See Tables 19 and 20 for computed similarity values for all Detroit River stations.

To summarize then, the upstream stations in the Detroit River are characterized by high population densities, richness, and diversity and are dominated by animals in the order Trichoptera. Samples taken in the section of the river below the Rouge River to Grosse Ile are extremely high in total numbers of individuals, with a subsequent low diversity and richness, high biomass and consisted almost exclusively of Tubificidae and Sphaeridae.

Table 18. DETROIT RIVER, SELECTED STATIONS COMPARED BY BIOMASS AND SHANNON-WEAVER DIVERSITY

Station	November 1973		May 1974	
	$\bar{X}$ Biomass	Shannon-Weaver	$\bar{X}$ Biomass	Shannon-Weaver
5	6.62	1.47	3.65	0.34
6	1.04	0.50	11.15	0.77
7	20.04	1.47	10.51	0.49
10	31.10	1.64	9.44	0.97
11	1.66	0.92	0.86	0.00
12	2.54	0.30	11.98	0.55
13	133.70	0.04	66.85	0.63
14	13.33	0.16	9.58	0.32
15	22.10	0.43	5.43	0.47
16	*	*	2.91	0.81
17	6.10	1.23	0.94	0.84

*no sample

Table 19. NOVEMBER SIMILARITY MATRIX, BENTHOS DETROIT RIVER

Station	5	6	7	8	9	10	11	12	13	14	15	18
5		0.40	0.85	0.42	0.40	0.24	0.38	0.40	0.14	0.35	0.53	0.00
6			0.32	0.33	0.31	0.00	0.22	0.00	0.00	0.00	0.17	0.00
7				0.74	0.60	0.19	0.30	0.32	0.11	0.29	0.43	0.00
8					0.47	0.29	0.15	0.17	0.18	0.43	0.38	0.00
9						0.13	0.14	0.31	0.00	0.13	0.12	0.00
10							0.55	0.40	0.67	0.83	0.57	0.00
11								0.44	0.50	0.36	0.62	0.00
12									0.57	0.40	0.67	0.00
13										0.67	0.36	0.00
14											0.57	0.00
15												0.00
18												1.00

Table 20. MAY SIMILARITY MATRIX, BENTHOS DETROIT RIVER

	5	6	7	8	9	10	11	12	13	14	15	18
5		0.33	0.40	0.57	0.40	0.00	0.00	0.00	0.18	0.25	0.33	0.00
6			0.80	0.86	0.80	0.00	0.00	0.22	0.00	0.00	0.00	0.00
7				0.67	1.00	0.00	0.00	0.00	0.00	0.00	0.40	0.00
8					0.67	0.67	0.00	0.00	0.00	0.00	0.00	0.00
9						0.00	0.00	0.00	0.00	0.00	0.40	0.00
10							0.57	0.18	0.46	0.40	0.50	0.50
11								0.25	0.40	0.57	0.80	0.57
12									0.29	0.18	0.22	0.22
13										0.77	0.55	0.55
14											0.75	0.75
15												1.00
18												1.00

Stations in the vicinity of Grosse Ile show medium numbers of individuals, diversity, and richness with low biomass and richness with low biomass figures. The stations in this area were dominated by Physa and Tubificids although some Ephemeroptera such as Hexagenia began to appear. The lake area stations are characterized by low to medium numbers, diversity, and richness with a low biomass and were dominated by mollusks.

Phytoplankton -

Phytoplankton populations in the St. Clair and Detroit Rivers were compared in terms of chlorophyll a, b, and c (μg/l), number of individuals/ml, percent dominance by major taxanomic groups, comparison of abundant species, species richness (S-1/lnN) and ($S/\sqrt{N}$), species diversity (Shannon-Weaver expression), and population similarity (2c/a + b). Contrary to other aspects of this survey, e.g., chemistry and benthic sampling, phytoplankton measurements were collected from four areas of the two rivers. This included transects in the upper and lower (upstream and downstream) portions of the St. Clair River and upper and lower (upstream and downstream) portions of the Detroit River.

Chlorophyll - The results of the chlorophyll measurements are presented in Tables 21, 22 and 23 and Appendix C-1; trends are shown by Figures 39, 40, and 41. Values are given for collections taken during November 1973 and May 1974. Measurements from the August 1973 collection were extremely variable, with large experimental error, and thus were not tabulated. The techniques were refined and greater sensitivity with less variability was achieved in later measurements. In most cases replicate samples had fairly similar values (Appendix C-1). During November the two stations in the upper St. Clair River (stations 1 and 2) showed nearly identical mean levels of the respective chlorophyll measurements although this did not hold true during May 1974 (Table 21). In the lower St. Clair River (stations 3 and 4) the November and May chlorophyll levels were similar. Table 21 further indicates that greater variability occurred in the Detroit River transects (stations 5-7 and 19-22) than in the St. Clair River transects.

Mean chlorophyll a levels were similar in the upper and lower St. Clair River during both the November and May collections (Table 22). However, the mean chlorophyll a levels between the upper and lower Detroit River differed between November and May (Table 22 and Figure 39). During November the mean level of chlorophyll a in the upper Detroit River was less than that measured in the lower Detroit River, however the opposite was true during May (Table 22). At either time the Detroit River produced more chlorophyll a (μg/l) than did the St. Clair River. This trend can be seen in Figures 40 and 41.

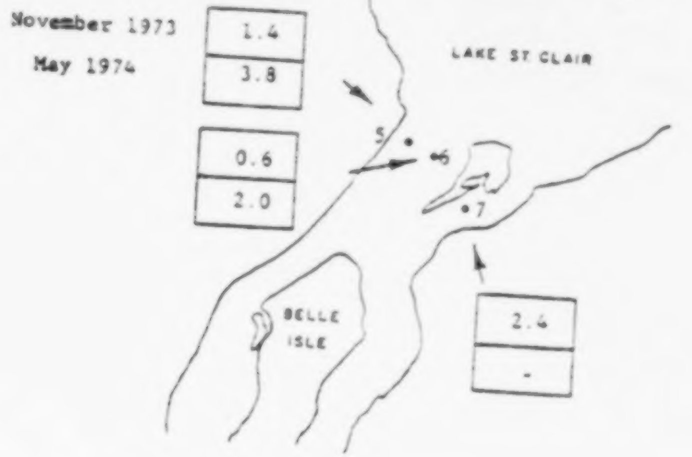
Table 21 DETROIT RIVER PHYTOPIGMENTS
Mean Chlorophyll a, b, c (μg/l)

Station	November 1973 Chl. a	Chl. b	Chl. c	May 1974 Chl. a	Chl. b	Chl. c
1	1.2	0.5	1.2	2.0	0.5	2.0
2	1.2	0.6	1.7	0.8	0	0.6
3	0.8	0.2	1.0	1.0	0.1	0.6
4	1.4	0.2	1.0	1.2	0.4	1.6
5	1.4	0.2	1.1	3.8	0.7	2.2
6	0.6	0.4	0.4	2.0	0.6	2.0
7	2.4	0.4	1.4	-	-	-
19	1.2	0.2	1.0	2.2	0.6	2.6
20	1.2	0.8	2.6	3.8	0.7	2.5
21	1.8	0.2	1.2	1.8	0.2	1.4
22	3.0	0.4	1.2	2.5	0.4	1.3

Table 22. MEAN CHLOROPHYLL a (μg/l) AT FOUR STUDY AREAS
Precision approximated according to Slack et al(51)

River Areas	n	Chlorophyll a Precision (μg/l) November 1973	n	May 1974
Upper St. Clair R.	4	1.2 ± 0.13	4	1.4 ± 0.13
Lower St. Clair R.	4	1.1 ± 0.13	4	1.2 ± 0.13
Upper Detroit R.	6	1.5 ± 0.11	4	2.9 ± 0.13
Lower Detroit R.	8	1.8 ± 0.09	8	2.6 ± 0.09

Figure 39. Detroit River mean chlorophyll a concentration (µg/l)


November 1973
May 1974
1.4
3.8
LAKE ST. CLAIR
5
6
0.6
2.0
7
BELLE ISLE
2.4
-

Detroit River phytopigments were measured at two locations, mile mark 3.9 (lower Detroit River) and mile mark 30.8 (upper Detroit River)

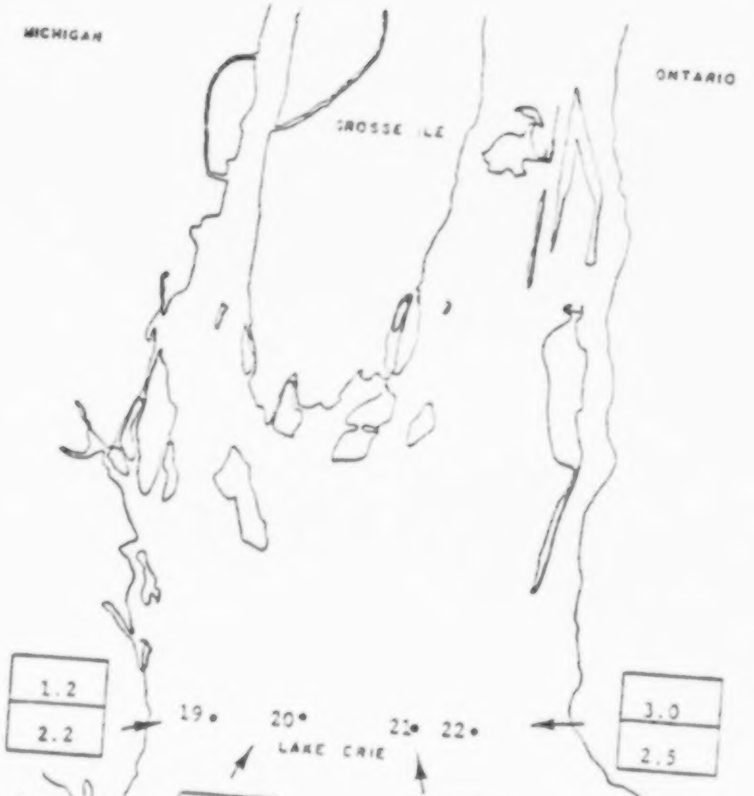

MICHIGAN
ONTARIO
GROSSE ILE
1.2
2.2
19
20
21
22
LAKE ERIE
3.0
2.5
1.2
3.8
1.8
1.8

Figure 40. Mean Chlorophyll a Concentrations (μg/l)
November 1973

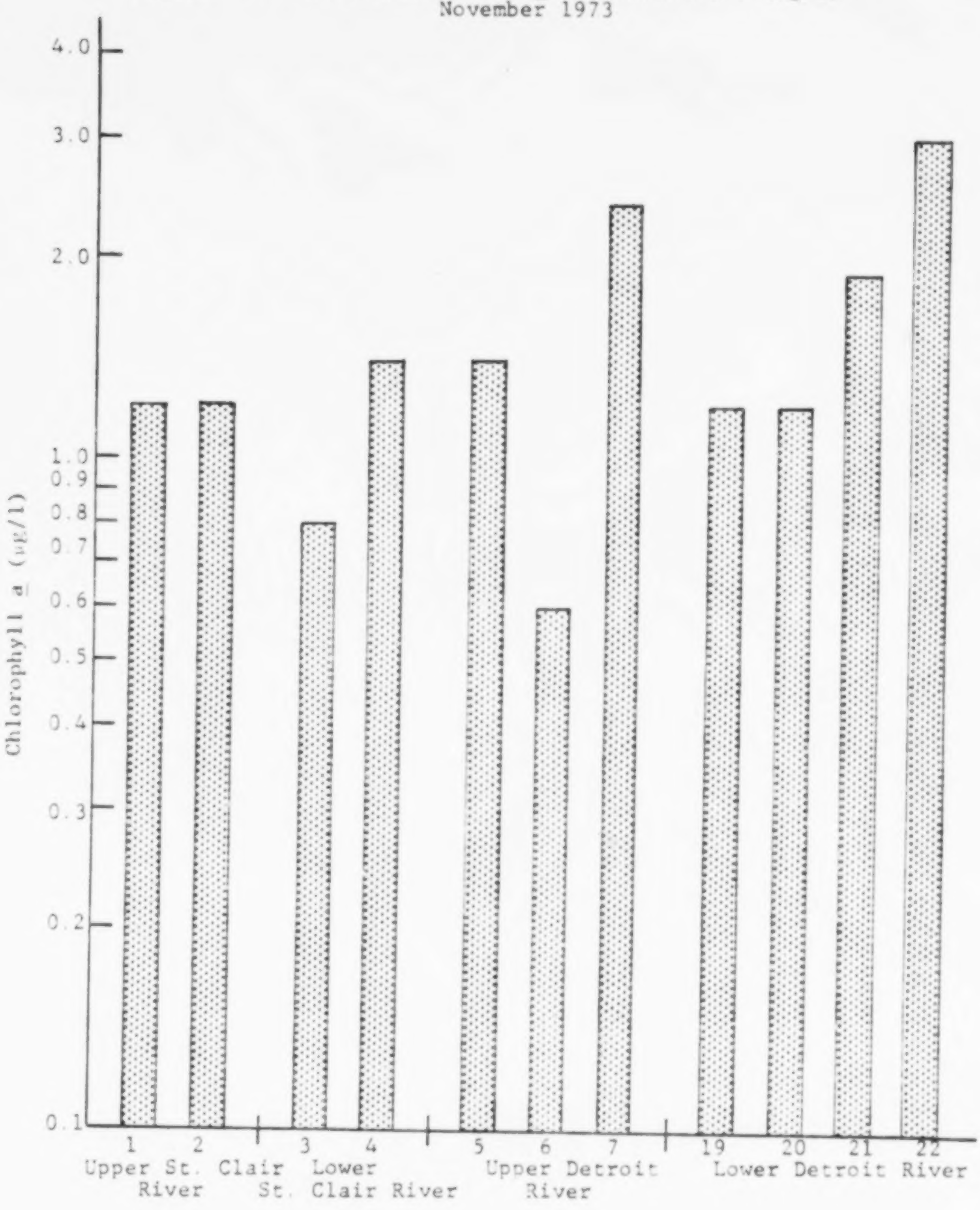
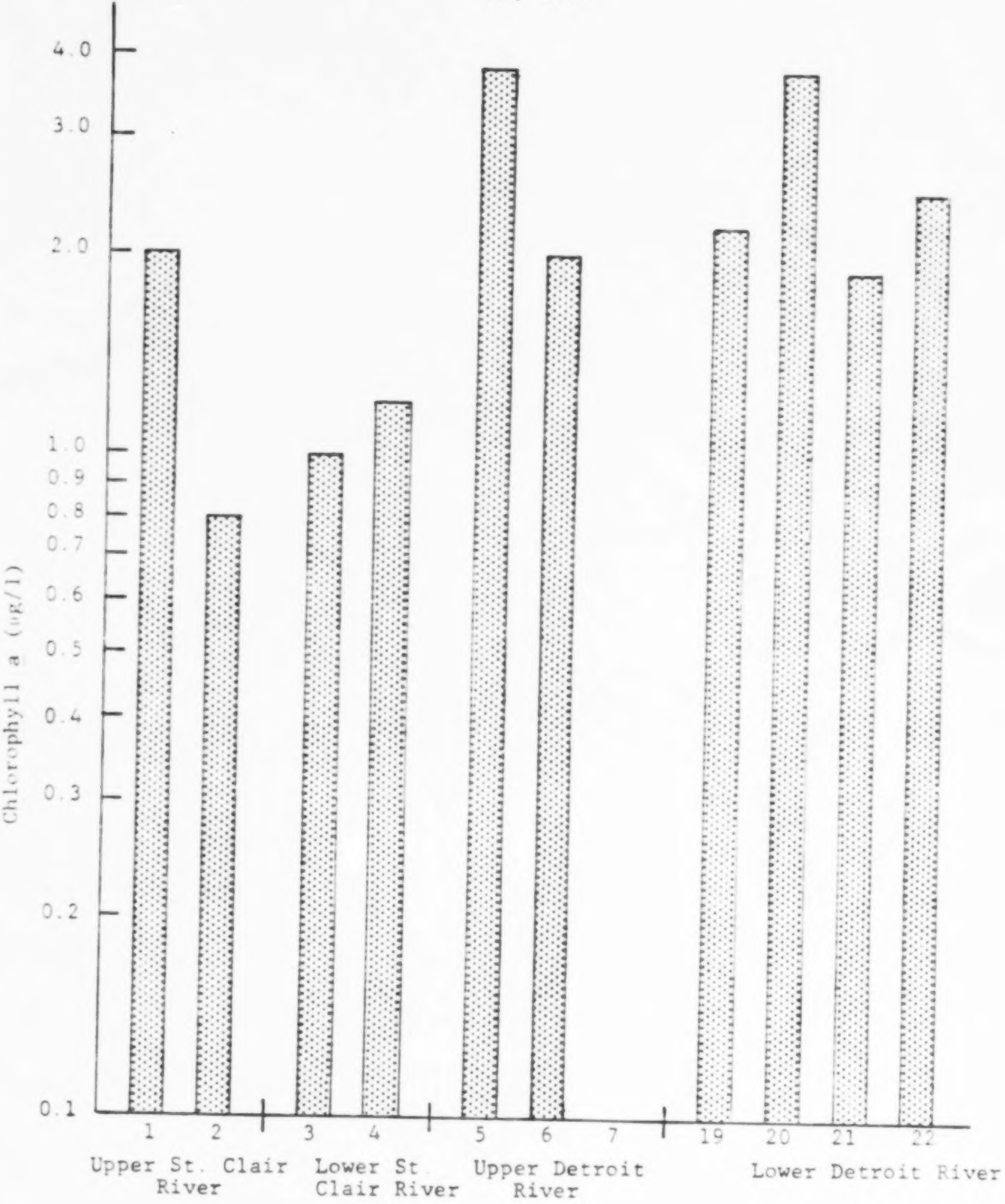


Figure 41. Mean Chlorophyll a Concentration (µg/l)
May 1974



The levels of chlorophyll b (μg/l) presented in Table 21 indicate that there was similar production in both the St. Clair and Detroit Rivers during November, while there was greater production in the Detroit River during May. Little emphasis should be placed on chlorophyll c as an independent measure, as the literature suggests this measurement is often variable and has a poor level of precision[53]. Chlorophyll c does indicate the abundance of certain algal groups and will be used in a ratio of chlorophyll c/a to show trends throughout this river system. A similar ratio, chlorophyll b/a, will be used in this manner.

Ratios as calculated for replicate samples are presented in Table 23. The ratio of chlorophyll b/a was most often greater during November than during May (Table 23), this is verified by the list of mean values by river and transect in Table 24. A similar trend was observed in the chlorophyll ratio c/a. Mean levels were always greater during November than during May (Table 24).

Table 24. VALUES OF CHLOROPHYLL RATIOS b/a AND c/a

	November 1973		May 1974	
	b/a	c/a	b/a	c/a
Upper St. Clair River	0.49	1.33	0.15	0.82
Lower St. Clair River	0.19	1.07	0.19	0.91
St. Clair River	0.34	1.20	0.21	0.87
Upper Detroit River	0.29	0.89	0.24	0.82
Lower Detroit River	0.29	1.05	0.21	0.78
Detroit River	0.29	0.99	0.18	0.79

Phytoplankton Abundance and Dominance - Total number of phytoplankton individuals were determined from microscopic examination of replicate samples and expressed as mean number of individuals/ml river water. The general trend observed was an increase in the number of species and total number of individuals from the St. Clair River through the Detroit River (Appendix C-2). Samples from the Detroit River carried the greater number of total species. Numbers of total individuals/ml seemed quite variable throughout the survey although during Novmeber 1973 there was little variation between all sample points. Mean total numbers of individuals/ml ranged from 227 - 9695 during August; 526 - 1147 during November; and 1113 - 3208 during May (Appendix C-2). The upper Detroit River (stations 5-7) carried the greater number of individuals/ml during August while having fewer species than other river areas. During the other surveys the downstream Detroit

TABLE 23. RATIOS OF CHLOROPHYLLS *c*/*a* AND *b*/*a* - ST. CLAIR AND DETROIT RIVERS

Station/Sample number	November 1973 Chlorophyll ratios		May 1974 Chlorophyll ratios	
	c/*a*	*b*/*a*	*c*/*a*	*b*/*a*
1A	1.30	0.40	0.47	0.11
1B	0.86	0.43	1.39	0.35
2A	0.85	0.23	0.50	0
2B	2.30	0.90	0.92	0
3A	1.00	0.33	0.50	0
3B	1.80	0.20	0.59	0.12
4A	0.80	0.07	1.44	0.31
4B	0.67	0.17	1.11	0.33
5A	0.82	0.18	0.55	0.15
5B	0.76	0.18	0.64	0.22
6A	-	0.14	0.93	0.26
6B	1.50	0.86	1.17	0.33
7A	0.46	0.14	-	-
7B	0.92	0.23	-	-
19A	0.93	0.27	1.38	0.33
19B	0.60	0.10	0.86	0.24
20A	2.83	0.67	0.75	0.20
20B	1.89	0.68	0.54	0.16
21A	0.84	0.21	0.64	0.16
21B	0.53	0.06	1.00	0.09
22A	0.26	0.12	0.48	0.19
22B	0.52	0.19	0.57	0.13

River transect (stations 19-22) produced the largest phytoplankton population. These trends can be seen in Table 25 and Appendix C-2. Mean number of individuals/ml were always less in the St. Clair River than in the Detroit River. The total plankton populations at the upstream and downstream Detroit River transects were similar (no./ml) when the means and variance are taken into consideration (Table 25).

Table 25. MEAN NUMBER OF PHYTOPLANKTON INDIVIDUALS/ml + ONE STANDARD DEVIATION

Date	Area		Mean
August 73	St. Clair River	392.5	98.9
	Detroit River	3137.0	3683.5
	Upstream	3466	5383.5
	Downstream	2808	2119.5
November 73	St. Clair River	645.8	100.4
	Detroit River	934.1	153.4
	Upstream	9257	233.3
	Downstream	940.5	103.1
May 74	St. Clair River	1386.0	241.3
	Detroit River	2476.8	751.4
	Upstream	2274.0	1213.4
	Downstream	2578.0	639.6

The dominant group of phytoplankton organisms was the diatoms (Bacillariophyta) in all cases. This held true at all stations during each collecting period (Table 26). During August and November 1973 the second and third dominants were the green algae (Chlorophyta) and blue green algae (Cyanophyta), respectively. The second dominant group during May 1974 was the Chrysophyta (golden-brown algae exclusive of the diatoms).

The dominant diatom species in the St. Clair River (stations 1-4) during August were Cyclotella spp., Stephanodiscus astraea, and Tabellaria flocculosa (Appendix C-3). Pelogloea bacillifera was the dominant blue-green alga while Chlorella vulgaris, Elakatothrix gelatinosa, and Selenastrum minutum were the dominant green algal species. Dominant species in the upper and lower St. Clair River were similar during August.

In the Detroit River (August 1973) the domiannt species were *Cyclotella* spp., *C. catenata*, *Melosira italica*, *Navicula* spp., *Nitzschia* spp., and *Stephanodiscus astraea*. *Cyanarcus*

Table 26. DOMINANT GROUPS OF PHYTOPLANKTON BY PERCENT
St. Clair and Detroit Rivers (Aug, Nov 73 and May 74)

Date	Station	Cyanophyta	Chlorophyta	Chrysophyta	Bacillariophyta	Others
August 73	1	13.2	17.5	2.5	59.0	7.8
	2	4.7	39.3	3.4	46.3	6.3
	3	7.5	11.6	7.2	62.9	10.7
	4	12.8	20.1	5.0	55.7	6.4
	5	7.0	15.0	0.2	77.5	0.3
	6	21.3	19.8	10.5	40.8	7.6
	7	5.2	19.4	2.6	71.9	0.9
	19	13.4	18.9	0.5	66.9	0.2
	20	6.4	12.0	0.8	80.7	0.5
	21	4.6	15.0	2.8	76.1	1.5
	22	-	-	-	-	-
November 73	1	23.6	4.7	1.0	68.6	2.2
	2	19.2	12.9	2.3	55.1	10.4
	3	22.9	10.0	2.2	60.6	4.3
	4	16.9	7.7	1.4	70.2	4.3
	5	5.9	9.2	6.9	67.4	10.6
	6	6.3	5.8	2.0	82.5	3.4
	7	3.5	18.0	1.8	69.7	6.6
	19	3.8	16.4	2.2	76.7	0.8
	20	4.6	6.8	2.4	73.8	12.3
	21	2.8	4.7	3.2	81.4	7.8
	22	2.5	16.9	5.2	58.9	16.1

Table 26. (cont.). DOMINANT GROUPS OF PHYTOPLANKTON BY PERCENT
St. Clair and Detroit Rivers (Aug, Nov 73 and May 74)

Date	Station	Cyanophyta	Chlorophyta	Chrysophyta	Bacillariophyta	Others
May 74	1	2.5	3.5	14.2	76.2	3.6
	2	2.1	4.1	13.9	65.7	14.0
	3	3.0	4.9	16.2	71.3	4.6
	4	2.3	2.9	19.9	71.8	3.3
	5	1.9	3.2	10.1	82.6	2.1
	6	2.5	3.0	14.1	79.4	1.0
	7	-	-	-	-	-
	19	1.0	3.7	0.4	94.3	0.6
	20	1.7	3.0	10.0	84.1	1.1
	21	2.0	4.3	13.0	79.9	0.6
	22	1.5	2.9	14.3	81.5	0

hamiformis and Marsoniella elegans were the dominant blue-green species, especially at station 5 of the upstream Detroit River transect. At the downstream transect several species of blue-green algae were equally abundant and the blue-greens were more diverse at the downstream transect than at the upstream transect (Appendix C-3). The August collections in the Detroit River had many green algal species of which Ankistrodesmus falcatus, A. spiralis, Planktosphaeria gelatinosa, Scenedesmus abundans, S. quadricauda, and Selenastrum minutum were common. As with the blue-green algae, the greens appeared to be more diverse at the downstream stations.

The order of dominance in the St. Clair River during November 1973 was the diatoms, blue-green, and green algae (Table 26). Of the diatoms Asterionella formosa, Cyclotella spp., Fragilaria crotonensis, Melosira italica, Stephanodiscus astraea, and Synedra spp. were equally common at all four St. Clair River stations (Appendix C-3). Fragilaria crotonensis was the most abundant, equalling between 20 and 30 percent of the total individuals/ml at the four St. Clair River stations. Coelosphaerium naegelianum, Microcystis aeruginosa, and Pelogloea bacillifera were the blue-greens which were common to all St. Clair River stations. Of these, Microcystis aeruginosa was consistently more abundant although an occassional species dominated this group at specific stations, e.g., Aphanocapsa elachista at station 1. The common green algae species were Ankistrodesmus falcatus, Golenkinia radiata, and Oocystis gloeocystiformis.

In the Detroit River during November the diatoms were dominant followed by the green and blue-green algae. The extent to which the diatoms were dominant was slightly higher in the Detroit River than in the St. Clair River (Table 26). The blue-green algae were only one-half to one-third as dominant in the Detroit River as in the St. Clair River and the degree of dominance of the green algae varied between stations. Common and abundant diatom species included Amphora sp., Asterionella formosa, Cyclotella spp., Fragilaria crotonensis, Melosira italica, Navicula spp., Nitzschia palea, Stephanodiscus astraea, and Synedra spp. (Appendix C-3). Blue-green species which were common included Chroococcus limneticus, Coelosphaerium naegelianum, Microcystis aeruginosa, and Oscillatoria minima, although this and other species of Oscillatoria were common at the downstream transect (stations 19-22). Common species of green algae included Ankistrodesmus falcatus, A. spiralis, Scenedesmus abundans, S. bijuga, S. quadricauda, and Selenastrum minutum. The species Dinobryon calciformis and D. sertularia of the Chrysophyta were also common at most stations (Appendix C-3).

Although the diatoms remained as the dominant group during May 1974, the Chrysophyta were of second importance rather than the Cyanophyta or Chlorophyta. The common diatom species in the St. Clair River were Asterionella formosa, Cyclotella spp., Fragilaria crotonensis, Rhizosolenia eriensis, Synedra spp., and Tabellaria flocculosa. The common and abundant species of Chrysophyta were Dinobryon sertularia and D. tabellariae (Appendix C-3).

Dominant diatom species in the Detroit River (May 1974) were Asterionella formosa, Cyclotella spp., Fragilaria capucina, F. crotonensis, Melosira varians, Synedra spp., and Tabellaria flocculosa. In addition to these, Cyclotella glomerata and Rhizosolenia eriensis were abundant at the downstream transect and less so at the upstream transect. Dinobryon sertularia and D. tabellariae were the dominant species of Chrysophyta. Of the blue-green algae the common forms were Oscillatoria hamelii and O. limnetica. Ankistrodesmus falcatus and A. spiralis were the common species of green algae in the Detroit River during May 1974 (Appendix C-3).

At several stations during all three collecting periods there was an abundance (7 to 16 percent) of "other forms" (Table 26 and Appendix C-3). These were phyto-flagellates and were classified as Rhodomonas lacustus and Chroomonas sp. It should be noted that those individuals recorded as Chroomonas sp. may not necessarily be of this taxon and should most probably be labelled as "Unidentified Flagellates".

Richness and Diversity - The data with regards to richness and diversity are summarized in Appendix C-3 and trends are depicted in Figures 42-47. For these comparisons, two richness formulas were used which are "ratio-type" expressions of which only one (S-1/lnN) was plotted as a histogram. In addition to the species richness calculations, species diversity ($\boxed{d}$) was determined by the Shannon-Weaver equation which is a "log-proportional" expression, with the numbers of each species being of relative importance.

Species richness increased from the upper St. Clair River to its downstream area during August 1973 and greatest richness occurred along the United States shore (Figure 42). At the upstream Detroit River transect species richness was slightly lower than found at the downstream St. Clair River transect. Richness was lowest along the United States shore at the upper Detroit River transect. In the lower Detroit River, species richness was greatest along the United States shore and lower near mid-channel. Species richness increased greatly from the upstream to the downstream Detroit River transects during August (Figure 42).

During November 1973, species richness was higher than during August at most stations

Figure 42. Phytoplankton Species Richness (S-1/lnN) - August 73

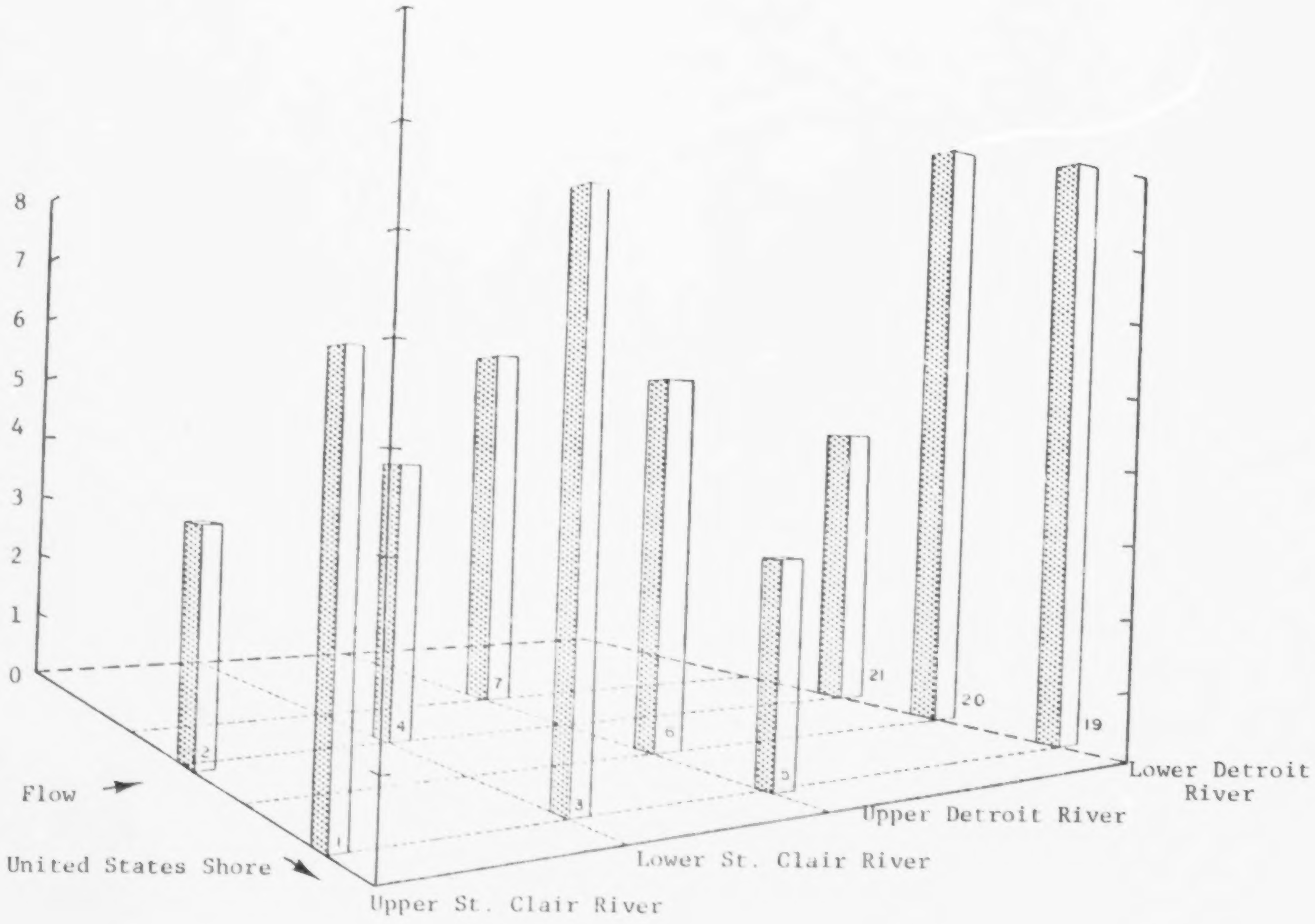


Figure 43. Phytoplankton Species Richness (S-1/lnN) - November 1973

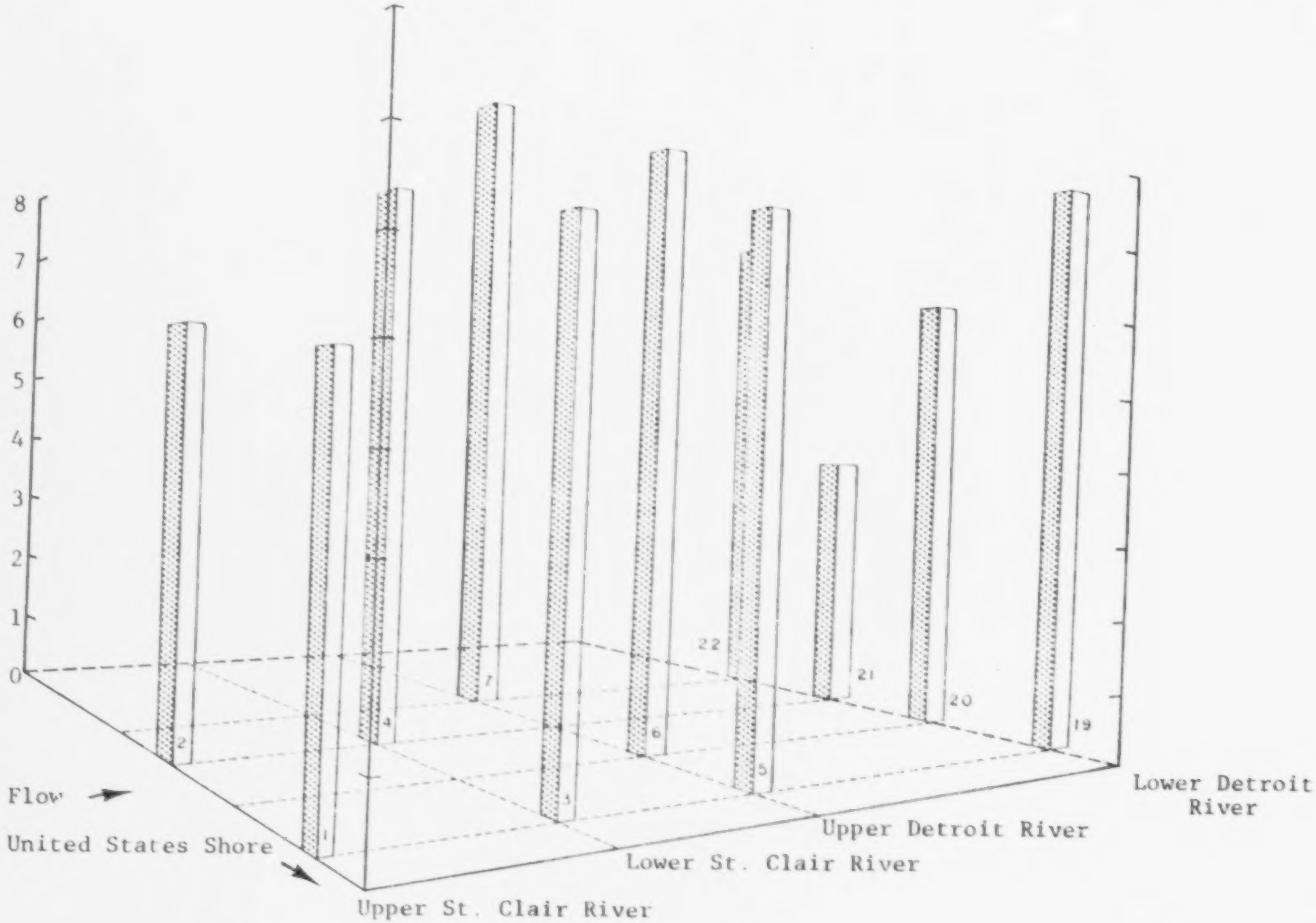


Figure 44 . Phytoplankton Species Richness (S-1/lnN) - May 74

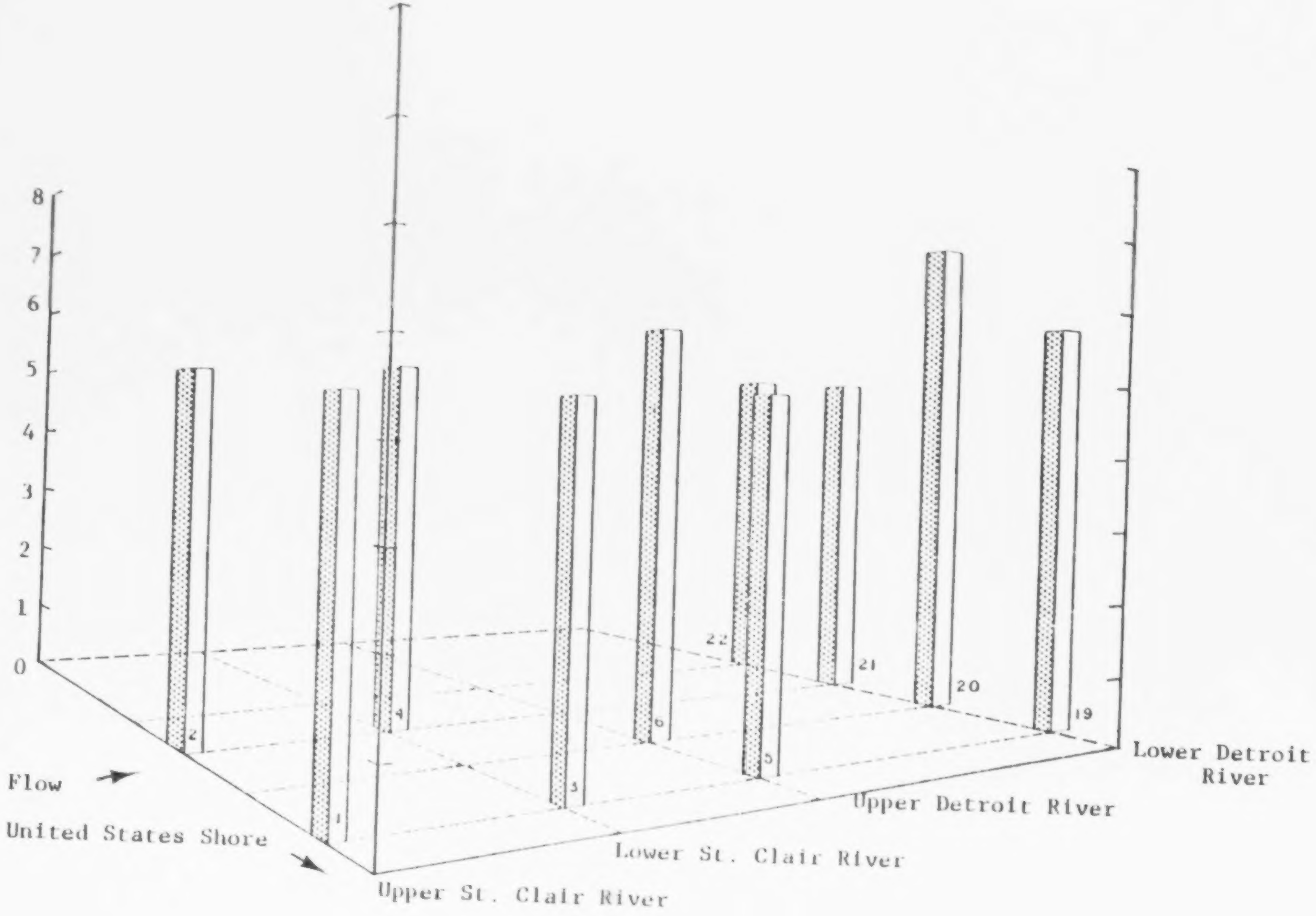


Figure 45. Phytoplankton Species Diversity ($\bar{d}$) - August 73

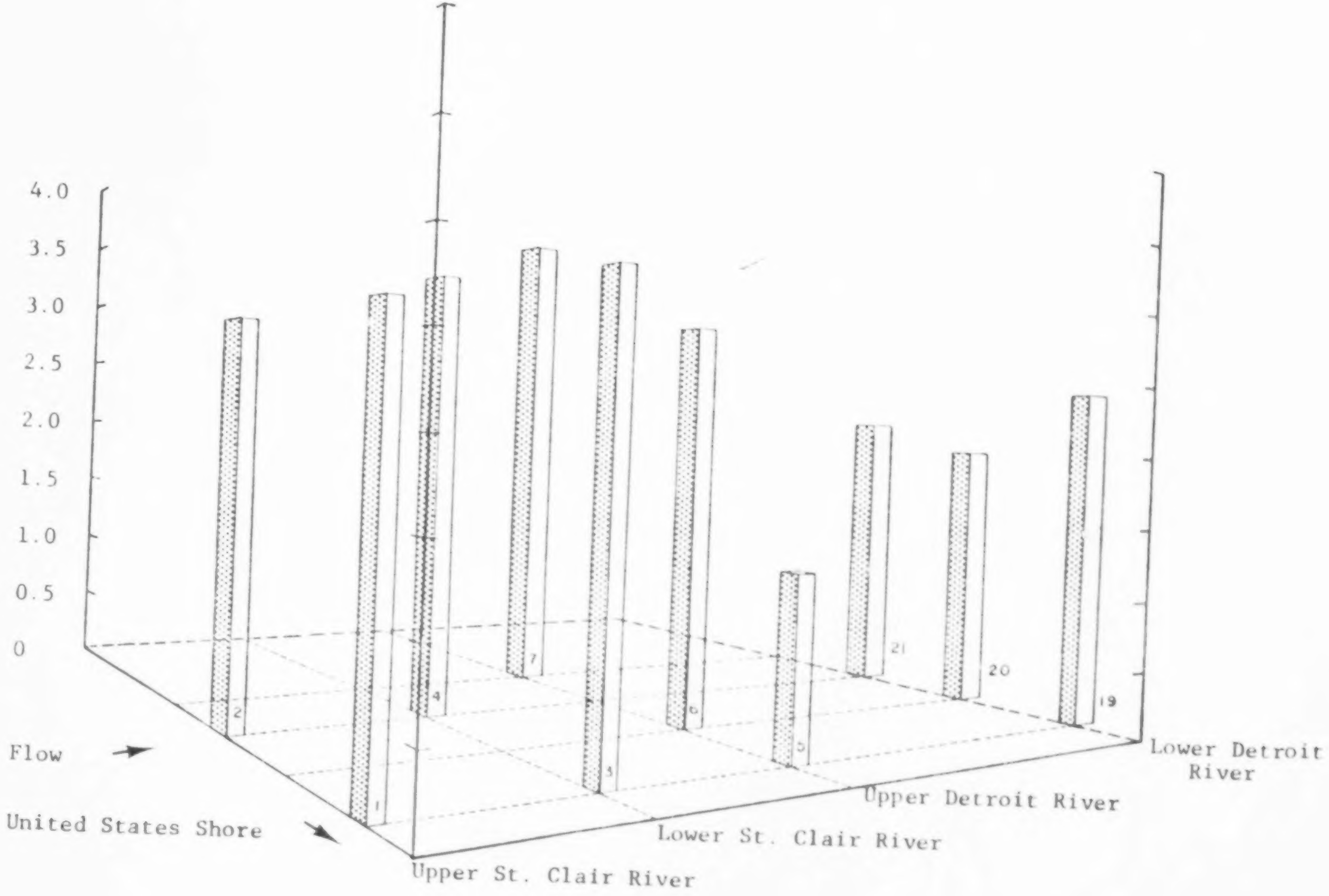


Figure 46. Phytoplankton Species Diversity (d) - November 1973

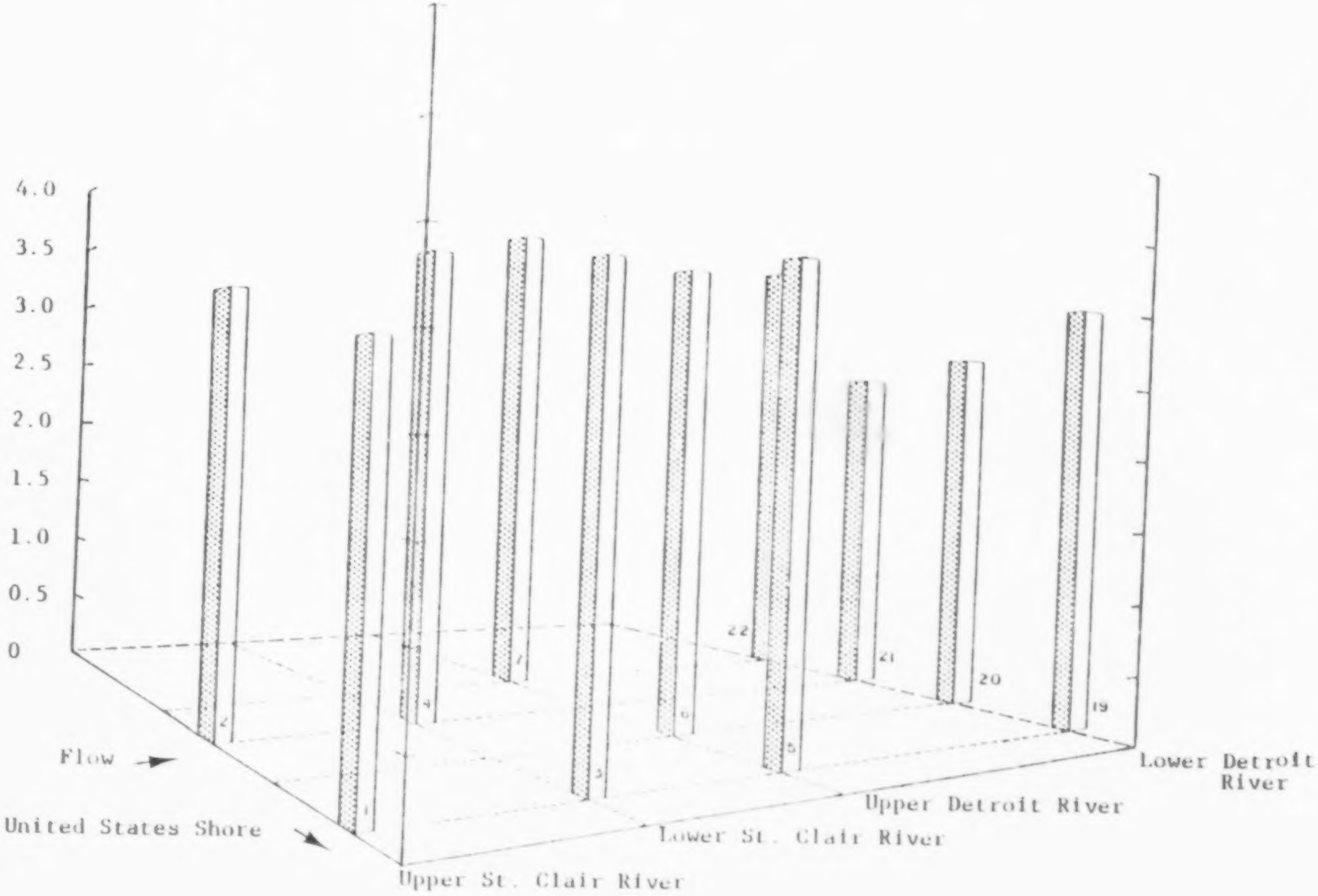
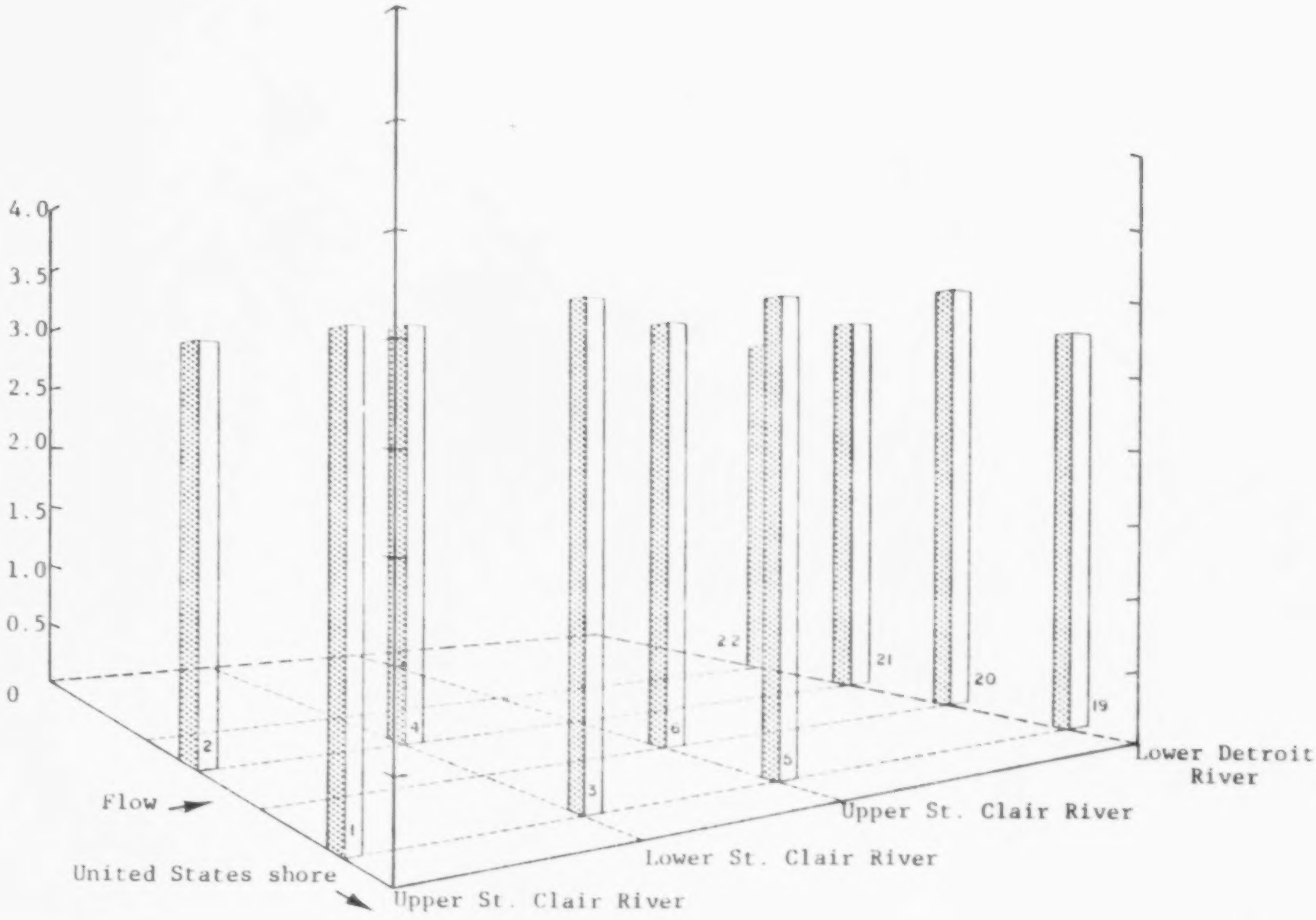


Figure 47 . Phytoplankton Species Diversity ($\bar{d}$) - May 74



(Figure 43). In the St. Clair River species richness increased from the upstream to the downstream transect, a trend similar to that seen during August. However, rather than one station exhibiting dominance over another within a transect, derived richness values within a transect were similar. High species richness occurred at the upstream Detroit River transect and increased from the United States shore, to mid-channel, to the Canadian shore. At the lower Detroit River transect the highest richness values occurred nearest the United States shore, decreased towards mid-channel, and increased again at station 22 (Figure 43). Mean species richness was higher in the upper Detroit River (6.99) than it was downstream (5.95).

Overall, species richness was lowest during May 1974 and was uniform throughout all stations with few exceptions (Appendix C-2, Figure 44). Derived richness values from the upstream Detroit River transect were very similar at the time of this survey, with a slight increase at the lower Detroit River transect. As occurred in the August and November collections, species richness values in the lower Detroit River were higher near the United States shore than at mid-channel.

Species diversity (d) exhibited more uniform trends than did species richness (S-1/lnN). During August 1973 diversity increased from the upper to the lower St. Clair River, decreased slightly at the upper Detroit River transect, and dropped to its lowest values at the lower Detroit River transect (Appendix C-2, Figure 45).

During November 1973, species diversity was higher at most stations than during August. Similar to the August collections, diversity increased from the upper to the lower St. Clair River and also increased at the upper Detroit River transect (Appendix C-2). In any comparison between transects diversity was similar. At the downstream Detroit River transect there was a decrease in diversity, although stations 19 and 22 had values similar to many of the upstream stations (Figure 46).

Greatest uniformity in species diversity between all stations was observed during May 1974. The only shift was a slight increase in diversity after the upstream St. Clair River transect. The Detroit River carried a slightly more diverse phytoplankton population than did the St. Clair River during May (Appendix C-2, Figure 47). Contrary to the low diversity seen at the downstream Detroit River transect during August and November, this transect produced a diverse population during May.

Similarity - There was a low degree of similarity between phytoplankton populations in the St. Clair River (stations 1-4) during August and November 1973 with somewhat higher similarity during May 1974 (Table 27). Stations 1 and 2 of the upstream St. Clair Rver transect were less than 50 percent similar (0.431) at the time of the August survey. Likewise, station pairs 1/3 and 2/3 were less than or equal to 50 percent similar. Greatest similarity was between station pairs involving station 4.

Parallel trends in similarity were observed in the St. Clair River during November (Table 27). Station pair 1/2 had the lowest similarity (0.522) which approaches the lower limit of similarity (arbitrarily selected as 50 percent). Station pairs 2/3 and 3/4 were the most similar, and similarity was highest in paired combinations involving stations 3 or 4 of the lower St. Clair River.

Highest overall similarity in phytoplankton populations in the St. Clair River was observed during May 1974. Station pair 1/2 which had no, or low, similarity at earlier dates, was similar at the 65 percent level (0.657) during May. Downstream station pairs exhibited higher similarity, and, as before, highest similarity usually involved paired combinations with stations 3 and 4.

Similarity of phytoplankton populations between stations in the Detroit River was low during August and November 1973. Values slightly below to slightly above the arbitrary 50 percent level of similarity were not uncommon (Tables 28 and 29). As seen in the St. Clair River, similarity during August was very low. There appeared to be slightly higher similarity within the downstream Detroit River transect than within the upstream transect during August. Cross pairing of stations between upper and lower Detroit River transects produced very low population similarity (Table 28).

During November there was higher plankton similarity between stations in the Detroit River than during August. When stations within a transect (upstream or downstream) were paired similarity was always greater than 50 percent, usually near the 60 percent level. Furthermore, there was good similarity between station pairs of different transects, e.g., 5/19, 6/20, 7/20, etc., with no value being less than 55 percent and most being above 60 percent.

High levels of similarity occurred during May 1974 (Table 30). Since no sample was obtained from station 7 there are fewer comparisons to make in the Detroit River. At the downstream transect, adjacent station pairs were more similar than nonadjacent pairs, i.e., 19/20, 20/21, and 21/22 were more similar than 19/21, 19/22, and 20/22. This

Table 27 PHYTOPLANKTON SIMILARITY - ST. CLAIR RIVER

Pirlot's Similarity Coefficient $\frac{2c}{a+b}$

A: August 73

Stations	1	2	3	4
1				
2	0.431			
3	0.500	0.459		
4	0.566	0.619	0.571	

B: November 73

Stations	1	2	3	4
1				
2	0.522			
3	0.579	0.759		
4	0.613	0.667	0.729	

C: May 74

Stations	1	2	3	4
1				
2	0.657			
3	0.627	0.725		
4	0.667	0.732	0.647	

Table 28 PHYTOPLANKTON SIMILARITY - DETROIT RIVER, AUGUST 1973
Pirlot's Similarity Coefficient $\frac{2c}{a + b}$

Stations	5	6	7	19	20	21	22
5							
6	0.464						
7	0.508	0.542					
19	0.500	0.457	0.526				
20	0.454	0.454	0.500	0.602			
21	0.533	0.533	0.603	0.500	0.554		
22	-	-	-	-	-		

Table 29. PHYTOPLANKTON SIMILARITY - DETROIT RIVER, NOVEMBER 1973
Pirlot s Similarity Coefficient $\frac{2c}{a + b}$

Stations	5	6	7	19	20	21	22
5							
6	0.660						
7	0.589	0.602					
19	0.653	0.602	0.615				
20	0.690	0.630	0.645	0.624			
21	0.611	0.550	0.568	0.543	0.686		
22	0.636	0.583	0.619	0.577	0.651	0.649	

Table 30. PHYTOPLANKTON SIMILARITY - DETROIT RIVER, MAY 1974
Pirlot's Similarity Coefficient $\frac{2c}{a+b}$

Stations	5	6	7	19	20	21	22
5							
6	0.779						
7	-	-					
19	0.729	0.744	-				
20	0.703	0.779	-	0.760			
21	0.737	0.711	-	0.643	0.725		
22	0.693	0.711	-	0.643	0.622	0.773	

same trend was seen during August and November (Tables 28 and 29). During May the cross-pairings between transects also produced high levels of similarity, none being less than 69 percent.

Discussion

Benthos

The St. Clair River is characterized by a benthic community adapted to living in a rapidly flowing system, with hard substration at the headwaters and somewhat more fines, detritus, etc. in the lower reaches. The preponderance of the Gastropod Goniobasis sp. at the headwaters illustrates this fact, as this organism has an extremely heavy shell and is able to maintain a hold on hard surfaced substratum in high velocity flow situations[54]. The environmentally critical condition throughout the St. Clair River would seem to be flow velocity and not pollution, posed on the observed benthic macrofauna. The species collected are intolerant to mildly tolerant to pollutant additions or presence[54]. The Detroit River, although influenced by current velocity, evidences major pollutional conditions throughout the benthic community in several regions. The transect at Peach Island shows a community unaffected by major pollutional sources. The presence of the Hydorpsychid caddisflies and Amphipods is characteristic of a healthy southern Michigan river. The lowered total numbers and diversity during the May survey was undoubtedly due to increased flow produced by snow melt and spring rains. From these initial stations located at the headwaters of the river to river mile 20 there is a progressive degradation of the benthic community. Below the reach associated with the Rouge River confluence to Mud Island an abrupt change in the benthos is evident. Samples taken between river miles 19.0 and 12.0W had severely limited benthic communities, all of which had population structures of greater than 70 percent tolerant species. This condition is indicative of severely polluted environments[57] (Figure 48). The fact that samples collected near Mud Island had not fewer than 98 percent tolerant forms, primarily Limnodrilus, is evidence of a higher polluted situation. The stations downstream from this area along the United States shore, and particularly through the headwaters of the Trenton Channel, also had very high levels of tolerant benthic forms, animals that can grow and develop in a wide range of environmental conditions. These species are generally insensitive to a variety of environmental stresses such as the highly organically enriched areas previously mentioned. The river below station 15 (river mile 12.0W) begins a natural recovery in the benthic community (Table 19), although this "recovery" is faster along the Canadian shore and in the main channel. However, at river mile 3.9, which can technically be considered Lake Erie, the converse is true with respect to presence of tolerant forms. Stations 21 and 22 have high percentages of pollution tolerant or facultative organisms. This condition is due to the shifting of bottom and not entirely to pollutional enrichment from farther upstream. The principal animals collected here were the Sphaeriidae, which are capable of surviving for sustained periods the moving and shifting substration by closing the mantle. The oligohumic Chironomid Tanytarsus was also collected in this area.

Figure 48. Percent tolerant versus intolerant taxa at Benthos stations in the Detroit River, November 1973 and May 1974.

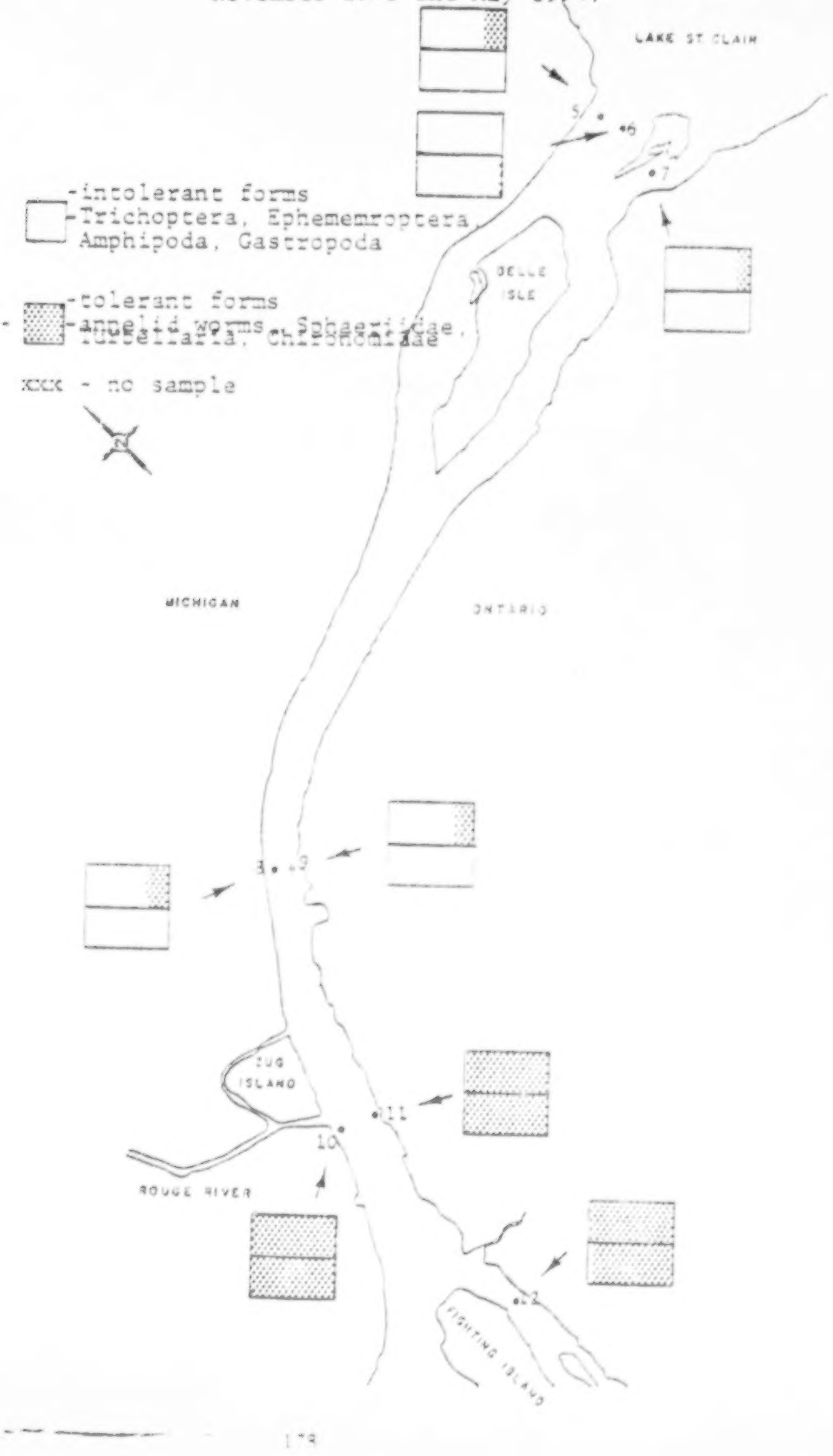
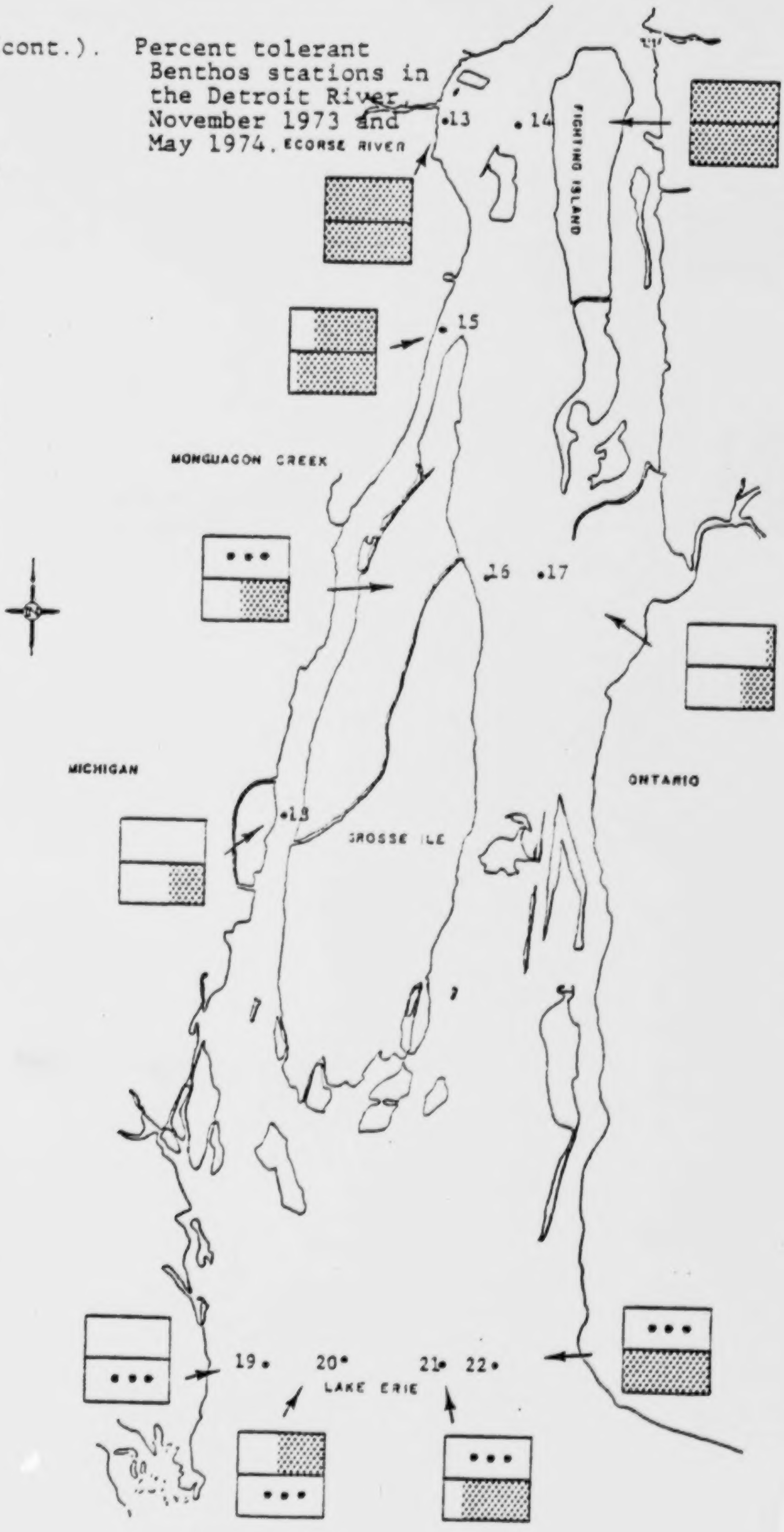

LAKE ST CLAIR
5
6
7
-intolerant forms
-Trichoptera, Ephememroptera, Amphipoda, Gastropoda
-tolerant forms
-annelid worms, Sphaeriidae, Turbellaria, Chironomidae
xxx - no sample
N
BELLE ISLE
MICHIGAN
ONTARIO
8
9
ZUG ISLAND
11
10
ROUGE RIVER
12
FIGHTING ISLAND

Figure 48 (cont.). Percent tolerant Benthos stations in the Detroit River, November 1973 and May 1974.


ECORSE RIVER
13
14
FIGHTING ISLAND
15
MONGUAGON CREEK
16
17
MICHIGAN
ONTARIO
18
GROSSE ILE
19
20
21
22
LAKE ERIE

The overall pattern of the macrobenthonic community in the Detroit River, then, is one of a relatively healthy and diverse assemblage from near the headwaters to just above the Rouge River. At this point the influence on the rivers benthos by industrial and municipal discharges, compounded by natural conditions, is altogether drastic. Low numbers of species are represented by very high numbers of individuals and the forms are largely tolerant to environmental stress.

Phytoplankton

Phytoplankton populations in the Lake Huron-Lake Erie connecting waters (i.e., the St. Clair and Detroit Rivers) are probably more important in terms of their potential rather than their present development. The occurrence and abundance of phytoplankton in a lotic ecosystem (running-water) is dependent upon many factors, and the extent of development is at most minimal when compared to a lentic system (standing-water). Limnologists who have studied lotic systems basically agree that rivers are dependent upon adjoining lakes, pools, backwaters, and tributaries for plankton organisms and that the development of these populations is affected by current velocity, turbidity, and age of the water[58,59,60]. River plankton is therefore a composite of a particular drainage and will vary, often significantly, with time and distance. Some species are able to reproduce to significant numbers in rivers depending on rate of flow and nutrient availability. Common river species are included in the genera *Fragilaria*, *Synedra*, *Asterionella*, *Cyclotella*, and *Stephanodiscus* and the green algae *Scenedesmus* and *Pediastrum*[58,59,60]. As current velocity slows, and temperature and nutrients increase, there are shifts in dominant species from diatoms to green and blue-green algae[54]. These conditions develop near the banks of a river before they do at mid-channel, thus initiating more "well-developed" plankton populations along the edges of a river (i.e., more total species and total individuals)[54,59,60].

When rivers flow into lake systems, the planktonic organisms are almost immediately subjected to a different set of conditions and respond accordingly. Some species decline in numbers while others reach "bloom" proportions depending upon their autecology, responding to changes in pH, alkalinity, nutrient availability, light penetration, temperature, sedimentation, and a wealth of other physical-chemical parameters. This in part dictates the development of phytoplankton in the St. Clair and Detroit River systems. Plankton from Lake Huron is subjected first to river conditions, specifically a fast flow rate as it enters the St. Clair River, and is later subjected to lake conditions as it enters Lake St. Clair. These same waters, after a relatively short rention time in Lake St. Clair, are again subjected to lotic conditions in the Detroit River, only to be eventually deposited in the western basin of Lake Erie.

The use of chlorophyll measurements gives an indication of algal biomass as it represents about one to two percent of the algal dry weight[61]. Also the amount of different chlorophyll forms (a, b, and c) give an indication of the taxonomic group or groups of algae which are present[61,62,63]. The data which have been presented show that the upstream and downstream transects of the St. Clair River supported similar algal biomass when expressed as chlorophyll a (μg/l), with the downstream transect being slightly lower. This is the probable result of the fast flow rate and the lack of new sources of plankton which are occassionally added to any river system. Lake Huron plankton, measured at the beginning of the St. Clair River, maintains a similar level as it passes to the lower St. Clair River measured near Algonac, Michigan before it enters Lake St. Clair. This is not to say that the population remained static. The population probably decreases and increases as the river descends to Lake St. Clair, however in total, it is not too different between the upstream and downstream areas.

This is further shown by little difference in the mean number of individuals/ml between river areas. Species richness, diversity, and population similarity indicate a changing plankton population from upstream to downstream in the St. Clair River. It appears as if different populations enter the St. Clair River on opposite shores and becomes mixed with distance downstream. Dominant species are similar, while there are shifts in the commona and occassional species. Population similarity stabilization as it nears Lake St. Clair. At no point did extremely low levels of species richness or species diversity occur in the St. Clair River. This river relfects Lake Huron phytoplankton and, due to physical factors, has little potential to develop into a nusiance phytoplankton population.

When chlorphyll data collected on this survey are compared to other studies similar results prevail. Data for 1973 from the Ontario Ministry of the Environment indicated an overall mean chlorophyll a level of 1.2 μg/l at the beginning of the St. Clair River. At a similar downstream transect the Ontario data indicates an overall mean chlorophyll a level of about 1.04 μg/. Analyses from this survey produced chlorophyll a values of 1.2 and 1.4 (±0.13) μg/l at the upstream transect and 1.1 and 1.2 (±0.13) μg/l at the downstream transect. Chlorophyll b levels in this survey and from the Ontario data are in the range of 0.2-0.6 μg/l.

From two collecting periods in the Detroit River (November and May) it was shown that the upstream and downstream areas produced similar, yet different, chlorophyll a levels. However, when mean values of all samples are considered there was a slight increase at the downstream area (i.e., 2.04 μg/l chlorophyll a upstream as opposed to 2.4 μg/l downstream). This is contrary to the St. Clair River trend which showed a slight decrease in chlorophyll a with distance downstream. Data from the Ontario surveys of 1973 indicated a decrease in chlorophyll a in going from the upstream to the downstream areas of the Detroit River (mean upstream concentration of 5.9 μg/l; mean downstream concentration of 3.4 μg/l). These data represent many more measurements than this survey, and extended over a 12 month period. In the current survey the little difference in chlorophyll b did not affect the chlorophyll b/a ratio which suggests similar plankton populations in the two areas of the Detroit River.

Species richness, diversity, and similarity support the trends shown by the chlorophyll data. The lower Detroit River was not greatly different from the upstream area. The downstream transect was shown to carry slightly more green and blue-green algal species during August and November. This trend, discussed earlier, occurs as rate of flow begins to decrease and temperature and nutrient availability increases. Dominant and common species were characteristic of river plankton as discussed earlier. Species richness and diversity were low at only one or two stations on different dates but were otherwise relatively high. Richness was at times greatest along the shore areas, a trend of river plankton suggested by other researchers[54,59,60], and values increased slightly in going downstream, except during November. This is the result of an increase in the number of species, as the total number of individuals did not change greatly. Shannon-Weaver species diversity tended to decrease at the downstream Detroit River transect, a trend usually associated with declining conditions of water quality. The degree of difference between the upstream and downstream transect was not, however, extreme.

A general overall trend of increasing numbers of individuals/ml was seen in moving from the upper St. Clair River to the lower Detroit River. Likewise species richness increased with distance from the St. Clair River to the lower Detroit River while species diversity was similar to slightly lower. This is not different from the trend shown in 1966 and 1967 where there was 540 asu/ml at Sarnia and 720 asu/ml at Windsor (1966) and 434 asu/ml and 79 asu/ml (1967) respectively[64]. An "asu/ml" is a calculated surface area of individuals, similar to, but less meaningful than, volumetric biomass determinations (1 asu/ml = 400 u^2).

At no time was there a plankton population of "bloom" proportions. Sawyer[65] has indicated that total inorganic nitrogen levels of 0.30 mg/l and orthophosphate-phosphorus levels of 0.01 mg/l are sufficient to initiate blooms of nuisance algae. Levels determined in the present survey were not of this magnitude. As stated earlier, the concern of the Detroit River and its phytoplankton population is its potential to produce "bloom" conditions of nuisance algae in Lake Erie. In order to better define this potential and the acute role of plankton in the Detroit River it is recommended that tests using the algal assay procedure[66] be pursued. A project of this nature could better predict the critical levels and ratios of nitrate, phosphate, and carbon.

SECTION VI

MATHEMATICAL MODEL FOR THE DETROIT RIVER

INTRODUCTION

A steady state mathematical model was developed for the Detroit River from its head at Lake St. Clair to its mouth at Lake Erie. The basic computer program used for this study is the Steady State Modeling Program (SSMP) developed by Canale and Nachiappan[67].

Several assumptions were made during the model construction. The first assumption of steady state conditions was inherent in the choice of SSMP as a model. This choice was based on several considerations including the type of river data generated from past and present monitoring programs; the industrial and municipal loading data available, and the general characteristic of the river system. As discussed previously in this report, the monitoring network along the river generally obtains samples once a month for six months during each year. Industrial surveys are performed by grab samples being taken at various times during the year. Recently, a self-monitoring program by the industries was initiated with grab or composite samples being taken a few times each month. Considering this data base, all simulation runs are based on average steady state conditions for a six month period in any given year.

SSMP is capable of handling one, two, or three dimensional analysis. A three dimensional system was chosen for the Detroit model in order to provide maximum flexibility in use of the model. This system is designed so that, in addition to considering the water interfaces (lateral and longitudinal) between segments, the sediment-water interface along the bottom of the river can also be included. As more sediment and sediment exchange information becomes available, it is hoped that this flexibility will allow the simulation of the water-sediment boundary exchange conditions for such parameters as nutrients and metals.

For most of the parameters to be discussed, conservative kinetics (reaction rate = 0) have been assumed. However, the model is capable of simulating first order reaction kinetics and a coupled system, such as BOD-DO.

Thus the Detroit River model developed during this study is a three dimensional, steady state model with an option of choosing a simulation for conservative substances or those which follow first order reaction kinetics.

MODEL FORMULATION

Theory

The development of the Detroit model is based on the laws of continuity. In examining the continuity equation (see Equation 1 and 2) it can be seen that two distinct types of mechanisms are involved in altering the concentration of a chemical or biological substance. The first mechanism involves the concept of reaction kinetics. Kinetic expressions can be dependent on a number of parameters including concentration, temperature, pH etc. The second mechanism involves mass transfer concepts including advective flow (bulk flow) and dispersive flow (small scale movement and concentration gradient effects).

It is not possible to solve Equation 2 directly for natural systems. Therefore it is necessary to make approximations which are equivalent to considering a body of water as a network of finite interconnected segments as shown in Figure 49. The steady state continuity equation with first order kinetics can then be reduced to the following:

$$V_k \frac{dC_k}{dt} = 0 = \sum_j \{ -Q_{kj}(\alpha_{kj} C_k + \beta_{kj} C_j) + E_{kj}(C_j - C_k) \} - V_k K_k C_k + W_k \qquad (3')$$

where:

C_k = concentration of water quality variable in segment k, (mg/l)

V_k = volume of segment k, (cft)

Q_{kj} = net flow from segment k to segment j (positive ward) (cubic feet per second)

α_{kj} = finite difference weight given by ratio of flow to dispersion, $0<\alpha<1$, dimensionless

β_{kj} = $1-\alpha_{kj}$

E_{kj} = dispersion mixing coefficient between segments k and j (cft/day) = $E_{kj} A_{kj} / \bar{L}_{kj}$

K_k = first order reaction coefficient in segment k for water quality variable C (day -1)

E_{kj} = dispersion coefficient between segments k and j (square miles/day)

A_{kj} = cross-sectional area between segments k and j (square feet)

$\bar{L}_{kj}$ = average of characteristic lengths of segment k and j (feet)

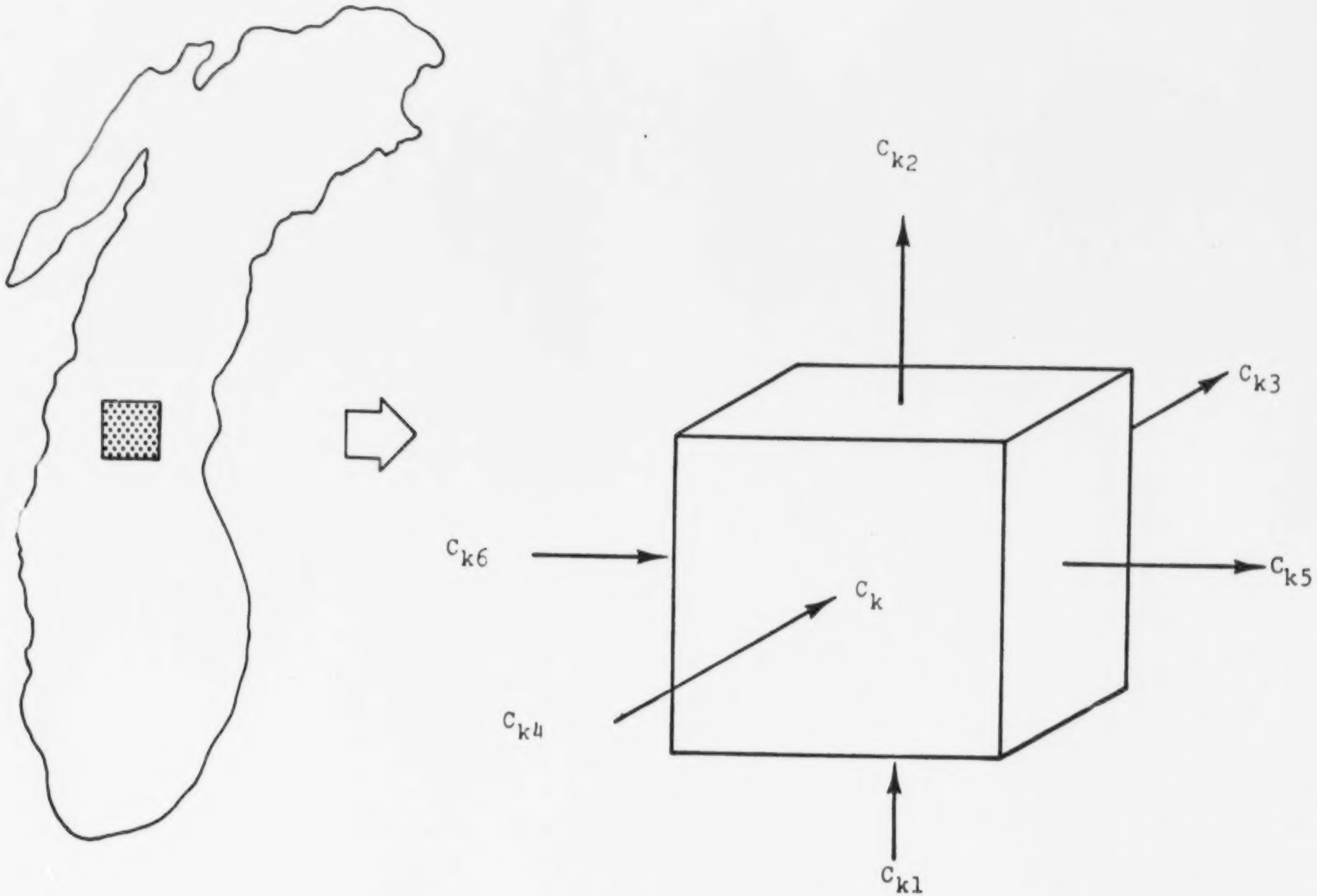
W_k = source (or sink) of variable C in segment k (pounds/day)

C_j = concentration of water quality variable in adjacent segments (mg/l)

$$\begin{array}{l}\text{Rate of Change of i}\\ \text{with time within a}\\ \text{cell}\\ \text{(weight/time)}\end{array} = \begin{array}{l}\text{Rate of Input of i}\\ \text{by convection, dis-}\\ \text{persion, sedimenta-}\\ \text{tion, or migration}\\ \text{from adjacent cells}\\ \text{(weight/time)}\end{array} - \begin{array}{l}\text{Rate of Output of}\\ \text{i by convection,}\\ \text{dispersion, sedi-}\\ \text{mentation, or}\\ \text{migration from}\\ \text{adjacent cells}\\ \text{(weight/time)}\end{array} + \begin{array}{l}\text{Rate of Production}\\ \text{of i by growth,}\\ \text{excretion, or}\\ \text{dissolution within}\\ \text{cell}\\ \text{(weight/time)}\end{array} - \begin{array}{l}\text{Rate of Disap-}\\ \text{pearance of i by}\\ \text{uptake, predation,}\\ \text{respiration, death,}\\ \text{or precipitation}\\ \text{(weight/time)}\end{array} \qquad (1)$$

$$\begin{array}{cccc}\textbf{Composition Change} & & \text{Hydrodynamic Mechanism} & & \text{Reaction Mechanism}\\ \underbrace{\frac{\partial C}{\partial T}}_{\text{ACCUMULATION}} & = & \underbrace{\nabla\cdot(E\nabla C)}_{\text{DISPERSION}} - \underbrace{\nabla\cdot(UC)}_{\text{BULK FLOW}} & + & \underbrace{S}_{\text{REACTION}}\end{array} \qquad (2)$$

Figure 49. Uniform Rectangular Volume


c_{k2}
c_{k3}
c_{k6}
c_{k5}
c_k
c_{k4}
c_{k1}

The above units for the parameters are those commonly used in practice and may be changed according to user preference.

For a river system represented by n segments (cells) the solution to equation 3 is obtained by solving a set of n simultaneous equations in n unknowns. There are several numerical methods for solving such a set of equations. SSMP uses a Gaussian elimination technique.

Equation three is applicable to single dependent variables, such as chloride, BOD and coliform. Other systems, such as dissolved oxygen, are coupled to other quality systems. The mass balance for a coupled system such as D.O. would be as follows:

$$V_k \frac{dC_k}{dt} = 0 = \sum_j -Q_{kj}(\alpha_{kj}C_k + \beta_{kj}C_j) + E_{kj}(C_j - C_k) + V_k K_{ak}(C_{sk} - C_k) - V_k K_{dk} L_k \pm W_k$$

where C_{sk} is the saturation value of D. O., K_{ak} is the reaeration coefficient in segment k, K_{dk} is the deoxgenation coefficient, L is the biochemical oxygen demand and ±W is now interpreted as sources and sinks of D. O. such as benthal demands and photosynthetic production or respiration. With L_k known from previous calculations, the final solution of Equation 4 is similar to the solution of Equation 3.

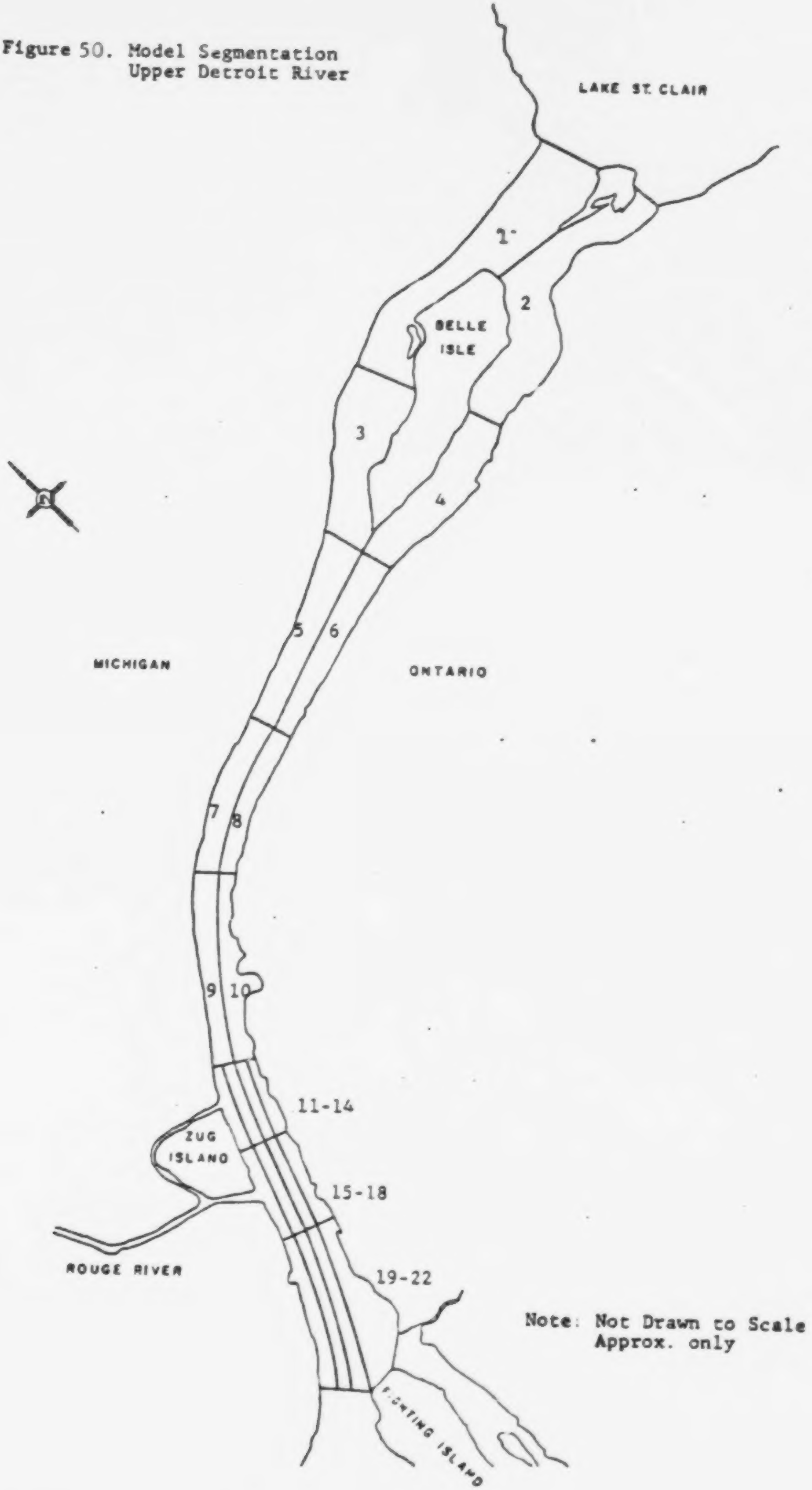
Thus, the river is represented as a three dimensional network of interconnected completely mixed segments, characterized according to the physical properties of a particular river system.

A more detailed discussion of the theory and solution techniques is given in the Appendix D.

River Characteristics and Segmentation

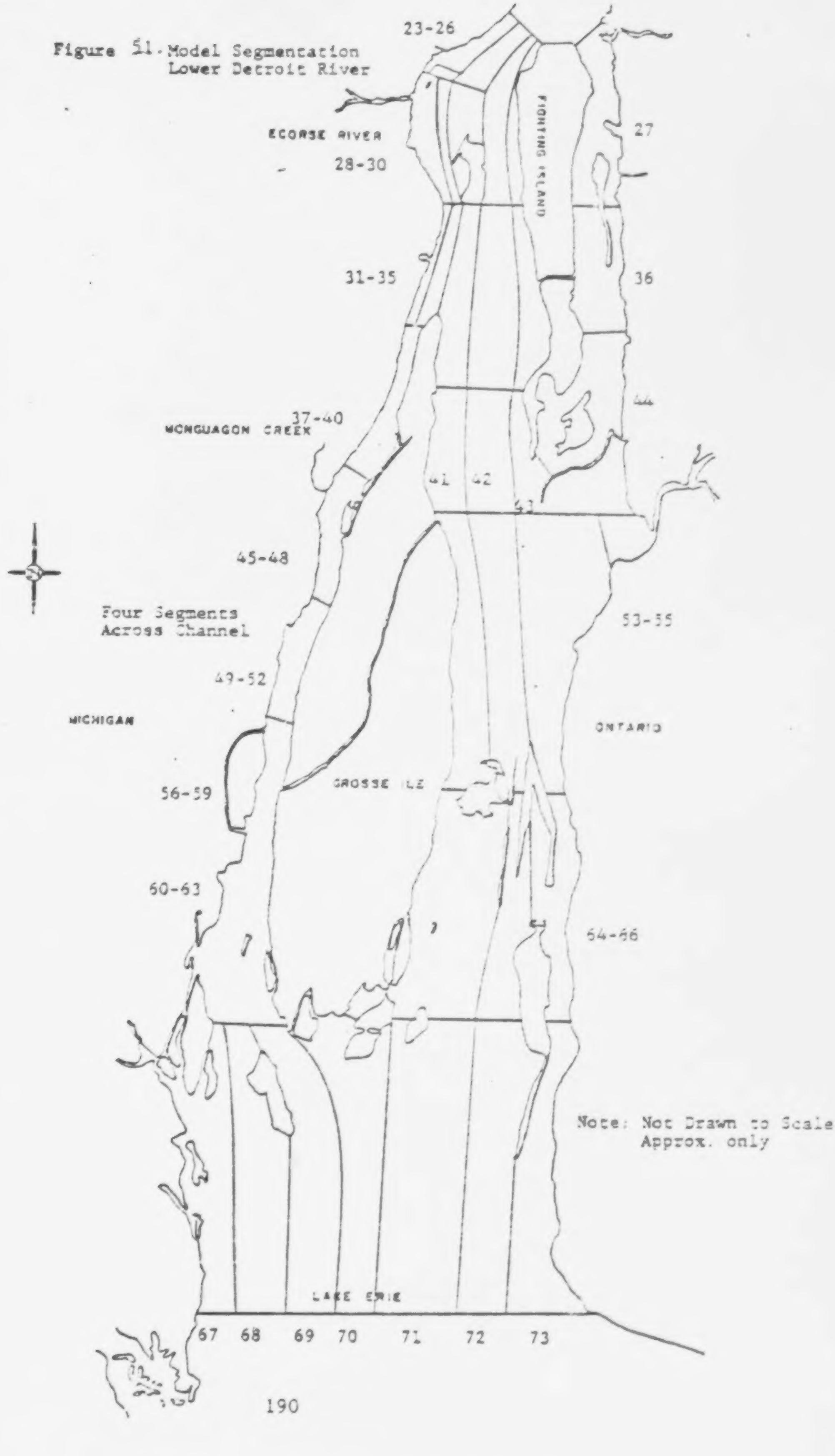
The Detroit River was divided into 73 segments. The resulting system of coupled segments is represented in Figures 50 and 51. The size, number and placement of the segments was based on an examination of available water quality data, location of major wastewater inputs and on the flow pattern of the river. In analyzing this information, it was found that the Upper Detroit River (Peach Island to Zug Island) was fairly uniform in the concentration of various pertinent parameters and contained few waste inputs. Therefore, large segments were used in this section of the river with generally two segments across

Figure 50. Model Segmentation
Upper Detroit River


LAKE ST. CLAIR
1
2
BELLE ISLE
3
4
5
6
MICHIGAN
ONTARIO
7
8
9
10
11-14
ZUG ISLAND
15-18
19-22
ROUGE RIVER
FIGHTING ISLAND

Note: Not Drawn to Scale
Approx. only

Figure 51. Model Segmentation Lower Detroit River


23-26
ECORSE RIVER
28-30
FIGHTING ISLAND
27
31-35
36
44
37-40
MONGUAGON CREEK
41
42
43
45-48
Four Segments Across Channel
53-55
49-52
MICHIGAN
ONTARIO
GROSSE ILE
56-59
60-63
64-66
Note: Not Drawn to Scale Approx. only
LAKE ERIE
67
68
69
70
71
72
73

the river and each segment approximately two miles in length. In the lower river (below Zug Island) the characteristics changed considerably. There are many waste inputs along the banks of the river and large concentration gradients were found between shoreline stations and center channel stations. As a result, a more detailed segmentation was used in this portion of the river. An example is the Trenton Channel running between the U. S. shore and Grosse Ile. This portion of the river is only 1000-1500 feet wide. However, because of the large concentration gradients, the river width was divided into four segments. The segments were also much shorter than the upper segments due to the large number of waste inputs. This more detailed characterization was followed throughout the Trenton Channel all the way to Lake Erie. The rest of the river was divided using similar considerations as discussed above (concentration gradients, waste inputs, flow routing). Islands located in the river were handled by starting new segments on each side of the Island and splitting the flow according to the available flow routing information. A few of the very small islands were incorporated within one segment. Several segments in the river were designed to contain water-sediment boundary conditions. The choice of these segments was based on general characteristics of the river (depth, water velocity, proximity to waste inputs, etc.) and on information gained during the core sampling portion of the survey program. The cross sectional area of the water-sediment interface was calculated for these designated segments and incorporated with the physical description in the model.

The schematization was prepared using U. S. Department of Commerce, National Ocean Survey, Lake Survey Center, navigation chart No. 400, scale 1:15,000. These maps were used to determine the cell widths, characteristic lengths, depths, and volumes. Flow routing for the river was obtained from the U. S. Public Health Service report[6] .

The flow rate in the Detroit River is exceptionally steady. The average discharge for the period of 1936 through 1973 was approximately 185,000 cfs. The average flow during 1962 through 1964 was 170,000 cfs. Flow rates have been somewhat higher in the last few years averaging 200,000 to 220,000 cfs. A table of flow rates used in the model for various years is given in Appendix D. Flow information was obtained from the U. S. Department of Commerce Lake Survey Center.

Kinetics

As discussed previously, both conservative substances and substances following first order reaction kinetics may be simulated using the model. In most cases the parameters chosen in this study were of a conservative nature. The type of kinetics assumed for each of the specific parameters will be indicated in the discussion with respect to the individual parameters.

Dispersion

Specific dye tracer studies were not part of this project and consequently it was not possible to calculate dispersion coefficients from such data. However, the Public Health Service report contained some dye tracer information on a qualitative basis, and also included maps indicating zones of pollution and the paths they traveled. Examination of river water quality information gathered since the Public Health report supported the various zones and pathways which had been defined earlier. This information, coupled with the large flow rates and swift velocities characteristic of the river, indicated that advective (bulk) flow was the major type of mass transfer in the river.

Several dispersion coefficients were tried ranging from .01 to .25 sq. miles/day. A coefficient of .05 sq. miles/day for lateral dispersion and a coefficient of .10 for longitudinal dispersion gave good results. These values were tested using chloride data for 1968 and 1969. A further discussion of this procedure is given in the chloride discussion below. These values appear reasonable in light of the characteristics of the Detroit River mentioned above.

VERIFICATION

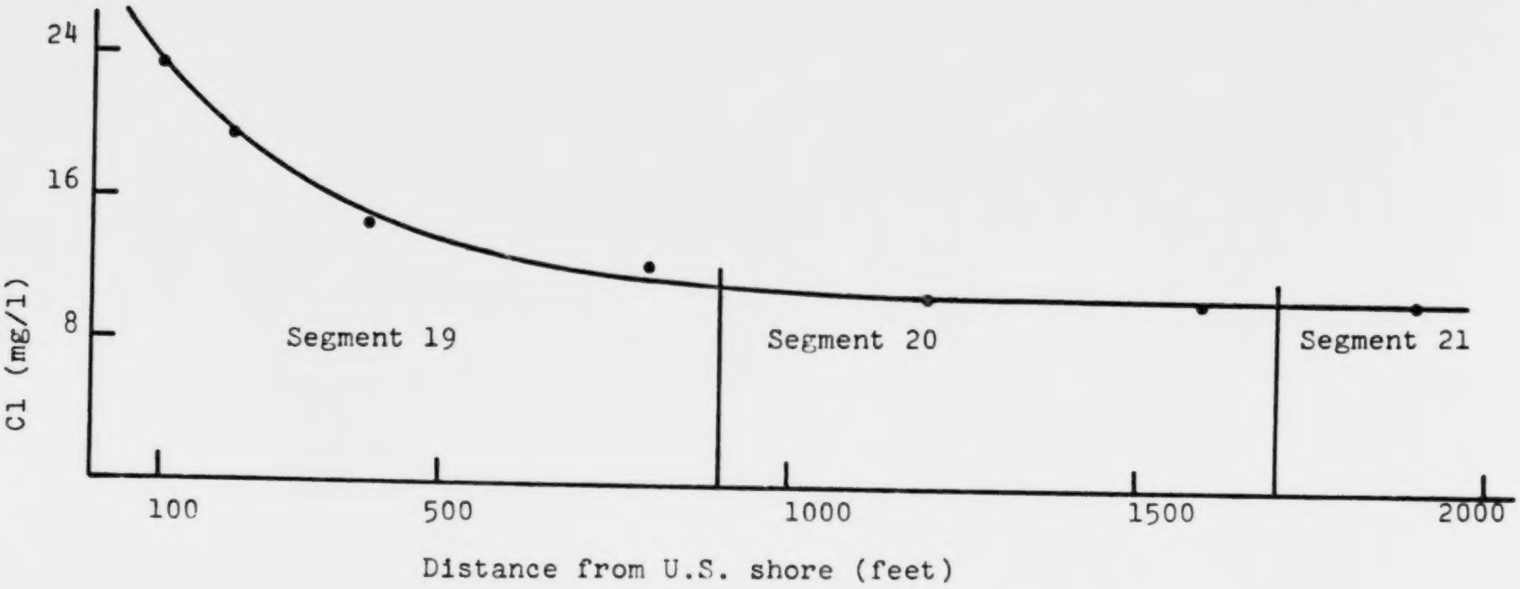
The previous section detailed the Detroit River model in its general form and considered the physical representation of the river. These characteristics (segmentation, flow rates, flow patterns, dispersion), when input to the general modeling program (SSMP), define the model specifically for the Detroit River system. As such, they remain constant regardless of which chemical parameter (chloride, phenol, etc.) is chosen for simulation. The following section will discuss the individual parameters which were modeled, and will consider the input variables which change for each specific parameter. These variables include input loads, boundary conditions, and reaction kinetics.

The river water quality data used in the verification for each parameter was obtained from various sources including, Public Health Service report, U. S. Environmental Protection Agency Storet System, and the Ontario Ministry of the Environment Water Quality Information System. Data obtained from these sources was averaged for each of the years investigated (i.e. at milepoint 14.6 station, 100 feet from shore, average chloride concentration, 1968, was 35 mg/l). These average values were then plotted versus distance from shore for each mile point along the river. Segments defined in the model were then matched with the appropriate mile points, and the widths of these segments were marked on the graphs at the proper intervals. The model treats each segment as a completely mixed cell and consequently, overall averages were obtained for each appropriate width by using individual station values, drawing a curve through them, calculating the area under the curve, and dividing by the width. An example is given below to illustrate this procedure.

Average chloride values for 1968 at milepoint 17.4W were obtained from the Storet System. Information was available for stations located at 100, 200, 400, 800, 1200, 1600, and 1900 feet from the U. S. shore. The average concentration of chloride for each of these stations was 23.6, 19.6, 14.4, 12.4, 10.8, 10.4, and 10.5 mg/l respectively. These averages were based on samples taken from April through October, 1968. Using these values, a plot of concentration versus distance from shore was developed. (See Figure 52). Three model segments (19, 20, and 21) are located at milepoint 17.4W. These widths were defined as 900 feet, 800 feet and 700 feet, respectively. Thus segment 19 includes the area from 0-900 feet from the U. S. shore,segment 20 includes 900-1700 feet and segment 21 includes 1700-2400 feet. These widths are marked on Figure 52. An average value for each segment was then obtained by calculating the area under the curve and dividing by the width. Average values were obtained in this manner for all milepoints at which data was available. These averages were then used to compare the actual river quality data with the concentrations predicted by the model.

Industrial and municipal waste input data was obtained from various sources, including the Michigan Water Resources Commission's monitoring programs, the industrial self-monitoring program, City of Detroit Waste Treatment Plant records, and the Public Health Service Report. The various industrial and municipal outfalls were located from maps provided by the Michigan Water Resources Commission. A listing of these outfalls and the segments into which they flow is given in Appendix D. Each industry contained one, two or many outfalls. In the case of those industries with several outfalls, the loading for each outfall was calculated, and then combined into one load for the industry. Loadings were obtained by averaging available data on a yearly basis. The type of data available differed widely in frequency of sampling, types of samples, parameters measured, etc. Where possible, averages were obtained from monthly or semi-monthly reports. For some cases the data was scattered, but could be used to obtain approximate values. In other

Figure 52. Average Chloride Concentration
Detroit River Dt 17.4W 1968



cases certain information, such as flow rates, was not available at the precise sampling time, but information was available from other time periods or other records. In these cases averages were again approximated and generally reported as ranges of values. Finally, in some instances little or no information was found, and best estimates had to be made based on data of previous years or other general information obtained. A complete listing of loadings used for various runs is given in Appendix D.

Boundary conditions were established from river quality data. In general, the concentrations found at milepoint 30.8 and milepoint 20.6 were similar, as no major industrial or municipal plants have outfalls in this section of the river. Consequently, boundary conditions were determined from data available at these two milepoints. These boundary concentrations were entered into the model to serve as a starting level of the various model simulations.

DISCUSSION

Chloride

During 1968 and 1968, a survey of industrial waste discharges along the Detroit River was conducted by the Michigan Water Resources Commission. This survey indicated that the major sources of chloride from the United States side of the river were Wyandotte Chemical Corporation (north and south works) and Pennwalt Chemicals Corporation. Other major sources were the Detroit Wastewater Treatment Plant, Wayne County Wastewater Treatment Plant and the Rouge River. The loading data provided by this survey was used as input data in the model. During the same time period, river water quality data was being obtained through the monitoring network.

Chloride was assumed to be a conservative substance for all simulation runs. Thus the reaction coefficient k was set equal to zero (k=0).

Having defined the input loads and kinetics for the system, the only remaining unknown was the magnitude of the dispersion coefficient. As discussed earlier, some information was available for use in estimating the lateral and longitudinal dispersion coefficients. Several coefficients were tried ranging from 0 to .25 miles^2 /day for lateral dispersion and 0 to 1.0 miles^2 /day for longitudinal dispersion. A reasonable fit of the data was obtained using .05 miles^2 /day for lateral dispersion and .10 miles^2 /day for longitudinal dispersion. The results for selected stations are presented in Figures 53-57. A complete

Figure 53 . Model verification - chloride
Detroit River - DT 14.6 and 12.0 - 1968

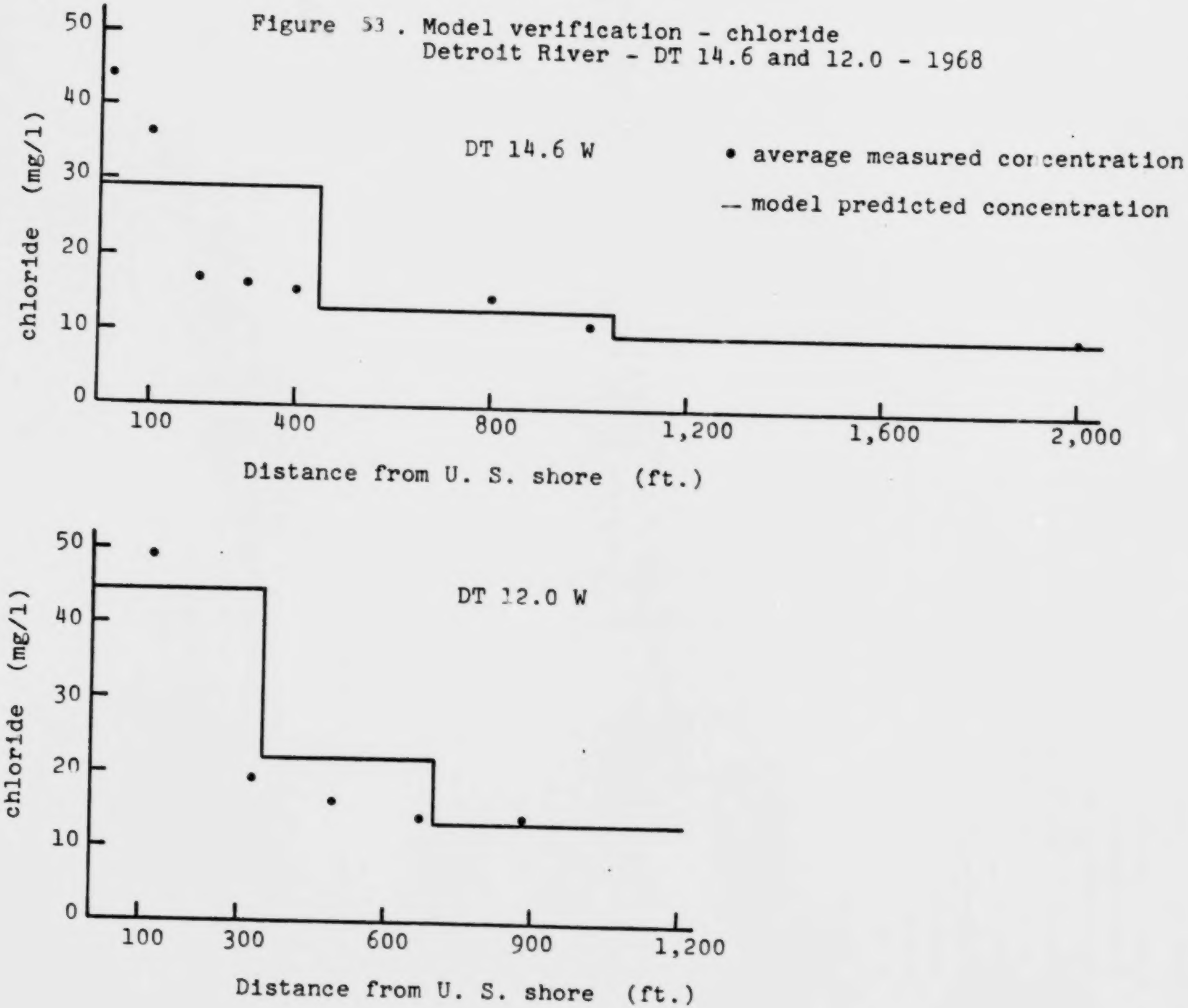


Figure 54 . Model verification - chloride
Detroit River - DT 8.7 W and 3.9 1968

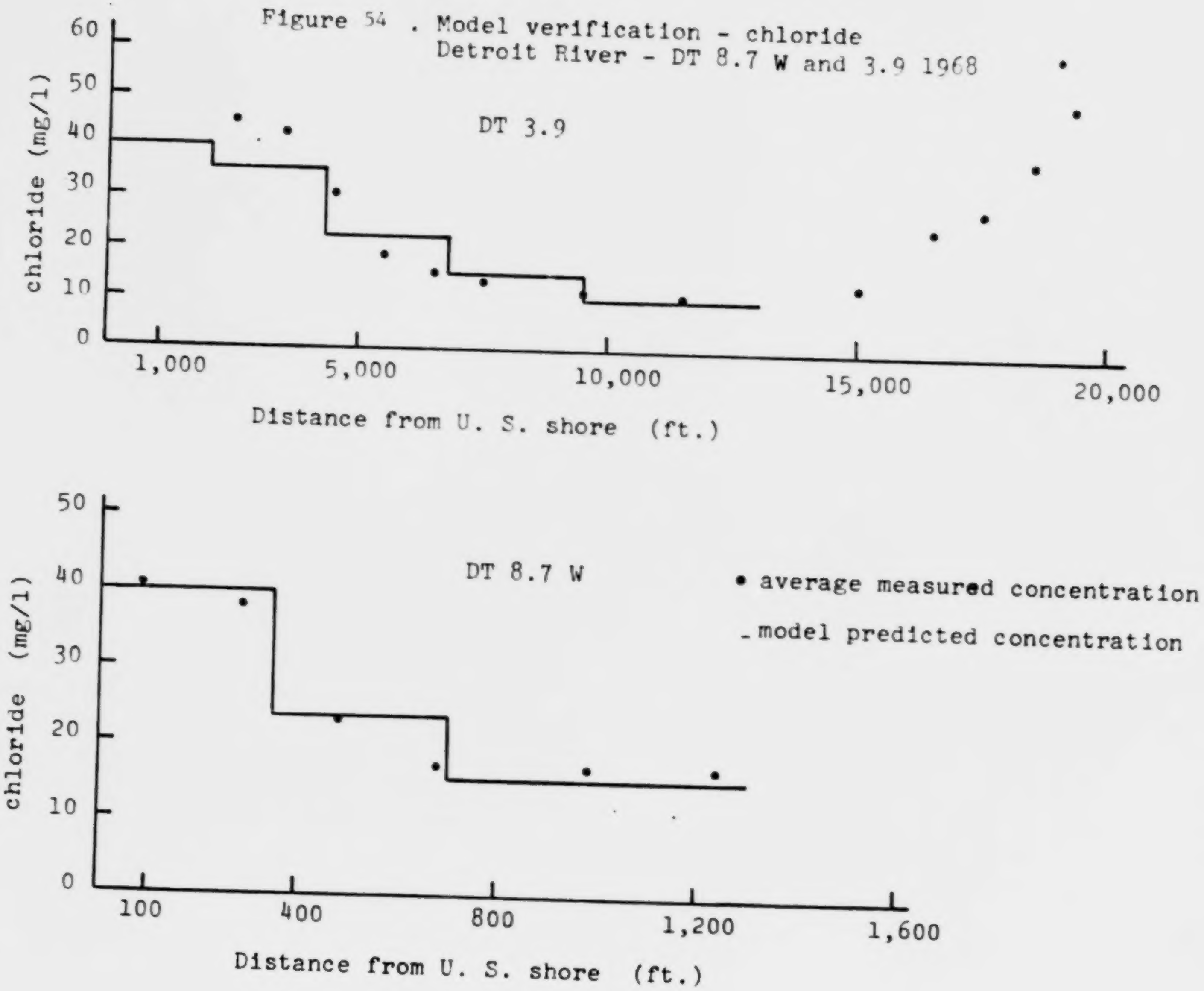


Figure 55. Model verification - chloride
Detroit River DT 20.6 and 17.4W 1969

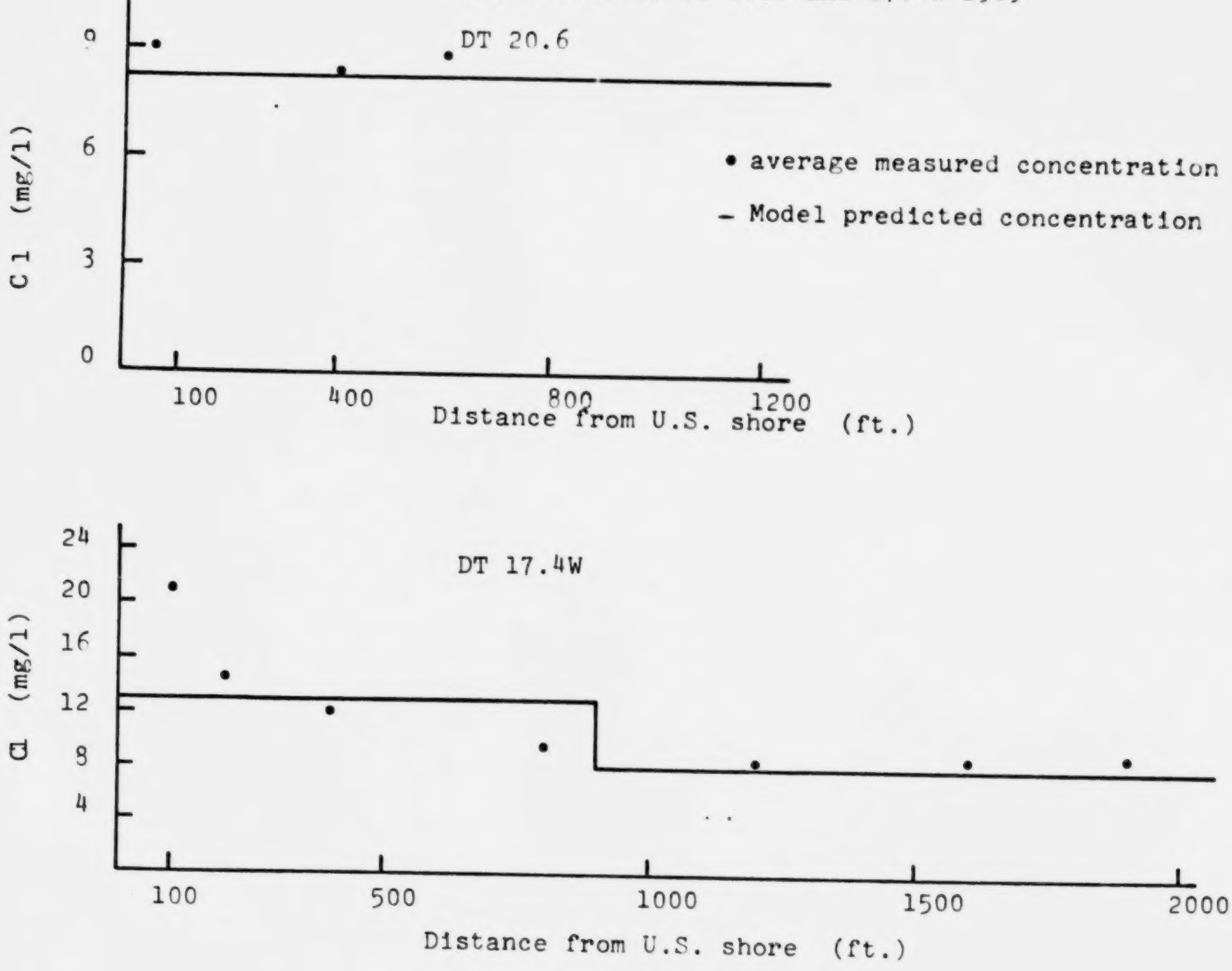


Figure 56. Model Verification - chloride
Detroit River - DT 14.6 W and 12.0W 1969

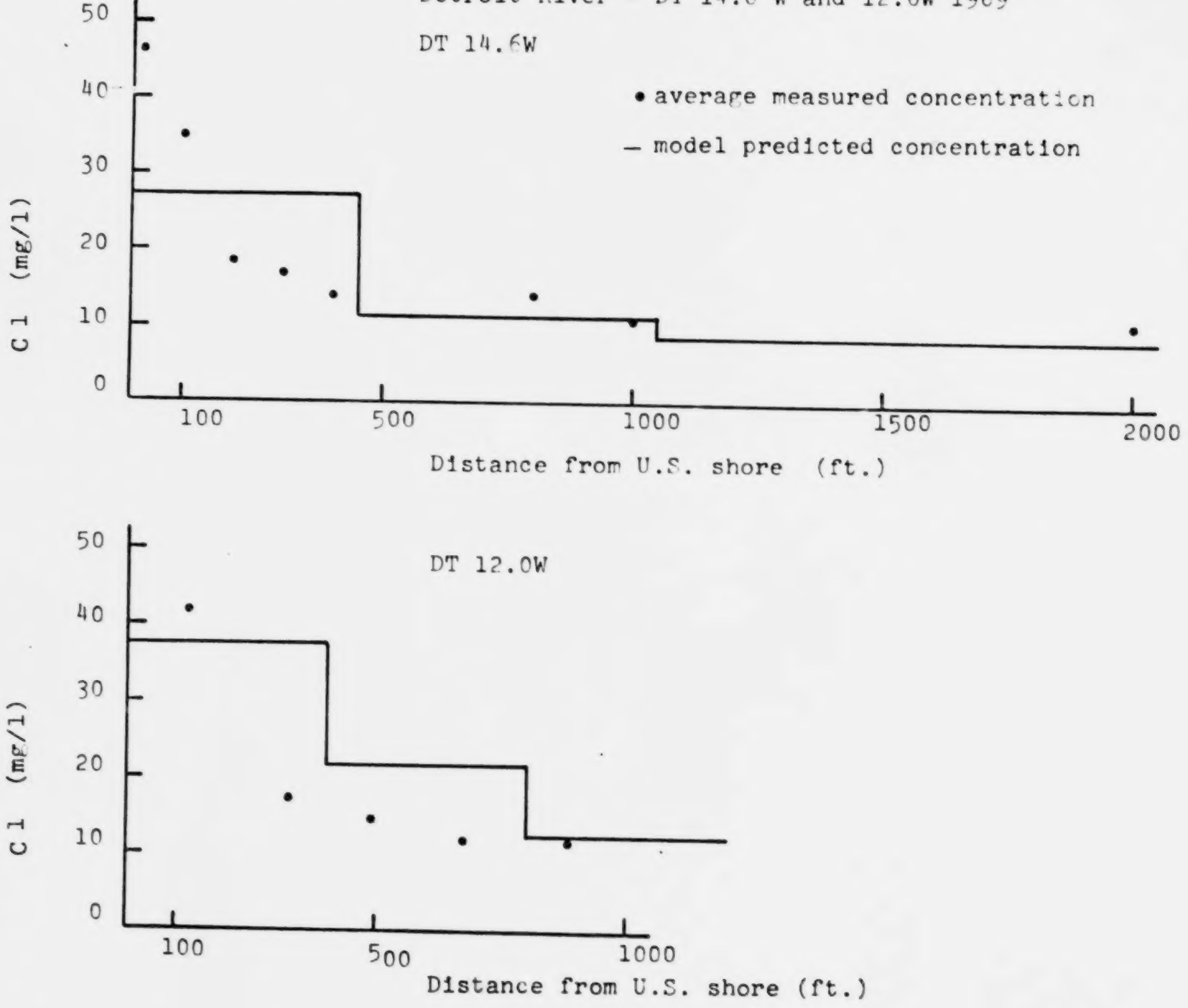
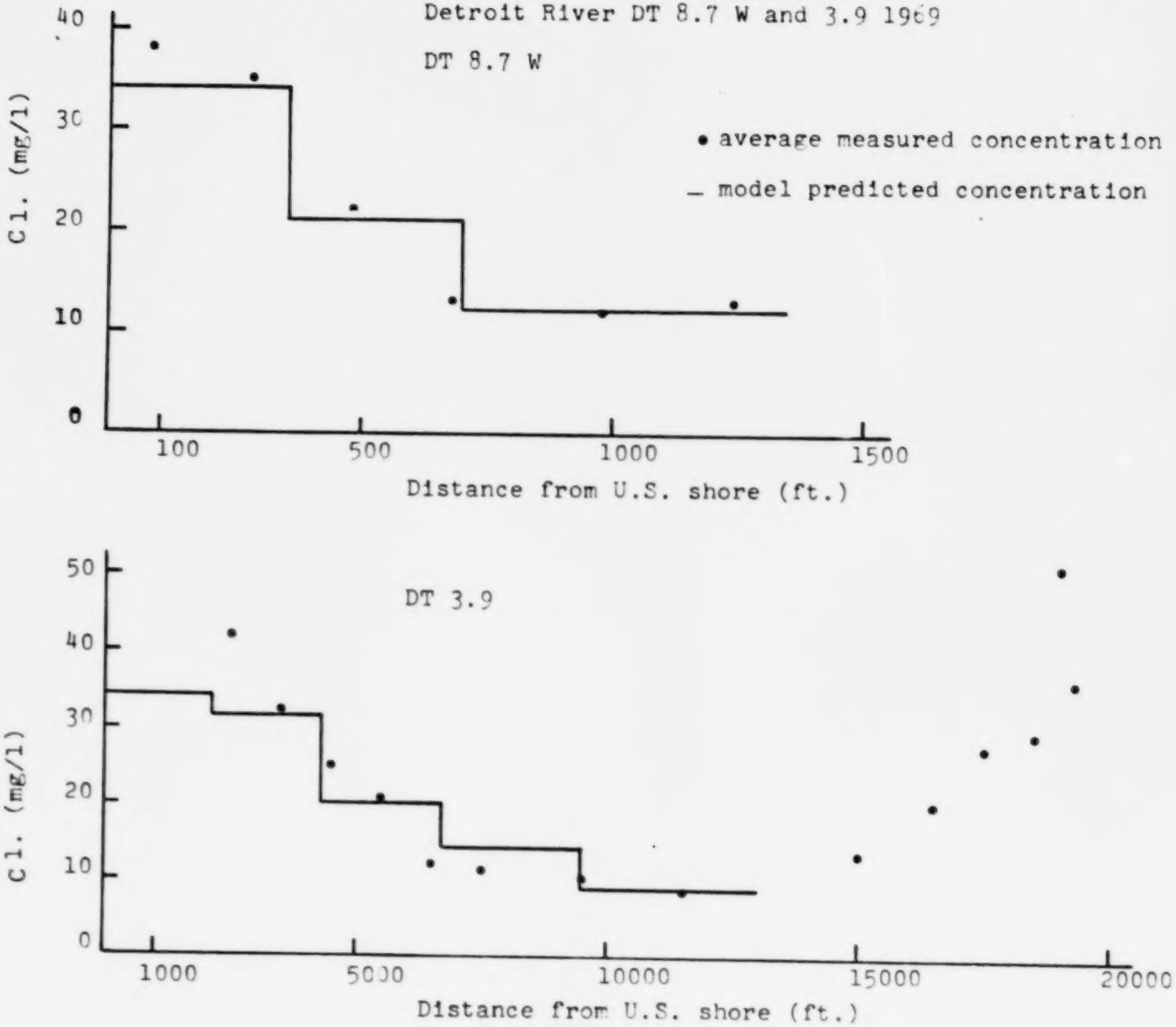


Figure 57. Model Verification - chloride
Detroit River DT 8.7 W and 3.9 1969



listing of industrial loads and model results is given in Appendix D. At this point, the results of the model simulation were quite good. However, for full verification, additional data; preferably under different loading conditions, needed to be examined.

Additional loading information and river water quality data were available for the years 1972 and 1973. The results for these simulations are presented in Figures 58-60. A complete listing of loads and model output is given in Appendix D. The comparison of model output with river data again was quite good. These runs were made without further adjustments of the dispersion coefficients.

The model was tested for five separate years (1963, 68, 69, 72, 73). In 1963, 68 and 69 the total loadings to the river were much higher than in 1972 and 1973. The reduction in loading and subsequent water quality improvement has been discussed in the trend analysis section of this report. The model simulation also reflected this water quality improvement.

During the test runs for 1963, (see Appendix D), using data from the Public Health Service Report, it was found that all predicted chloride levels were lower than the measured concentrations. Upon further examination, however, it was found that this should be expected. In the Public Health Service Report, a mass balance of chloride was presented which indicated that the measured loadings accounted for only a portion of the total chloride measured in the river. Thus, it would be expected that predicted levels using these loads would be somewhat lower than actual values. The spatial distribution predicted by the model did follow the general pattern of the measured values. By increasing the loading levels, to account for the discrepancy in the massbalance, the results correlated with the river data. This case serves to illustrate the point that a model is only as good as the data available.The analyst's care in choosing proper input data and the subsequent interpretation of the results is an important part of using a model as a tool. In this case, the results of the model indicated a problem, and upon further examination of the data, the discrepancy between loading data and river levels was found. Thus, the results of model supported the results of the Public Health Service Report from which the input data had been taken.

Overall the predicted levels for each year agreed quite well with observed data. In each case, it was possible to predict the average concentrations of chloride in the river using only waste input data and the appropriate flow rates. The dispersion coefficent was chosen based on 1968 data and was not changed in the simulation for other years. This same

Figure 58. Model Verification - chloride
Detroit River DT 20.6 and 19.0 1972

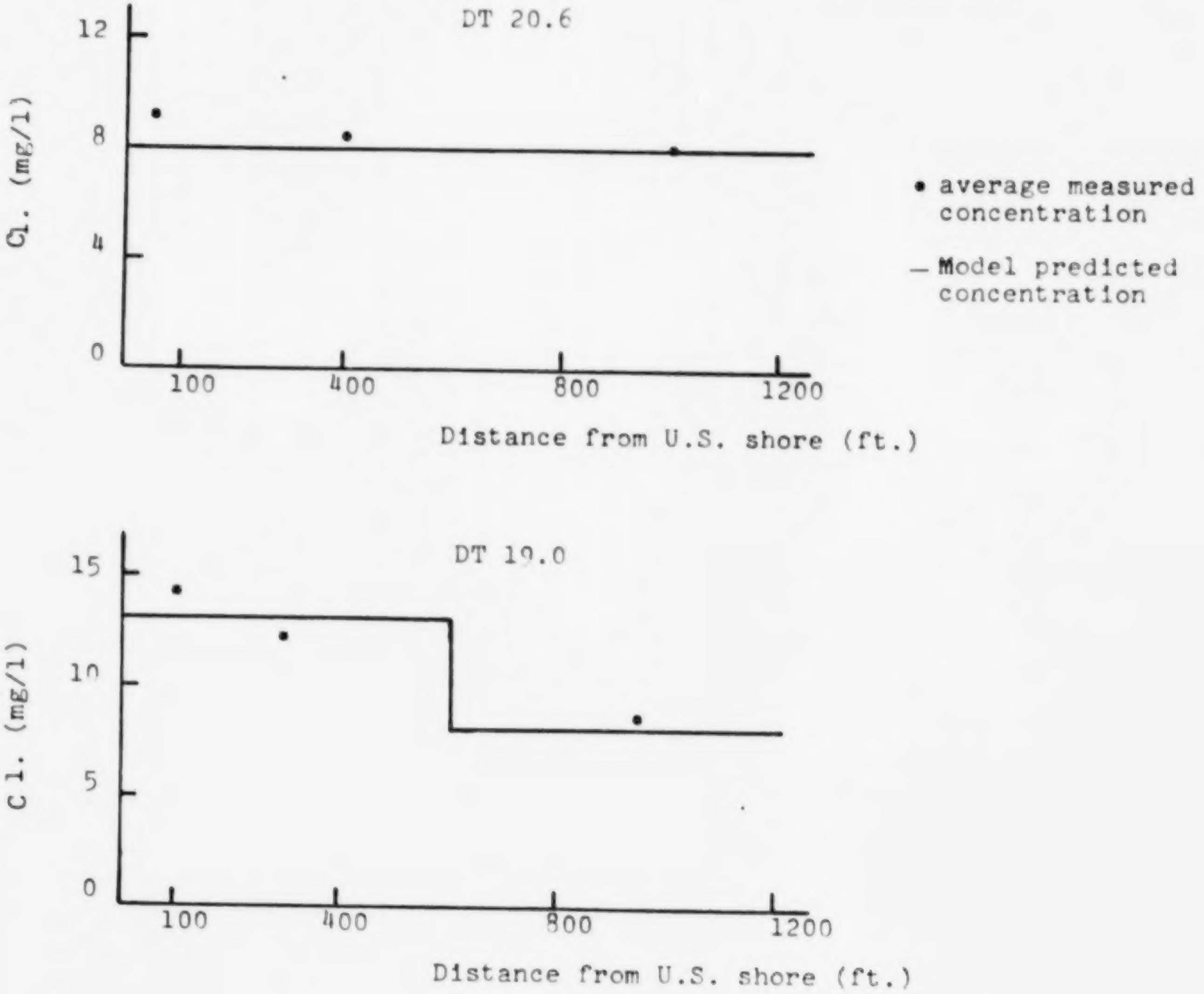


Figure 59. Model verification - chloride
Detroit River - DT 14.6W and 12.0W 1972

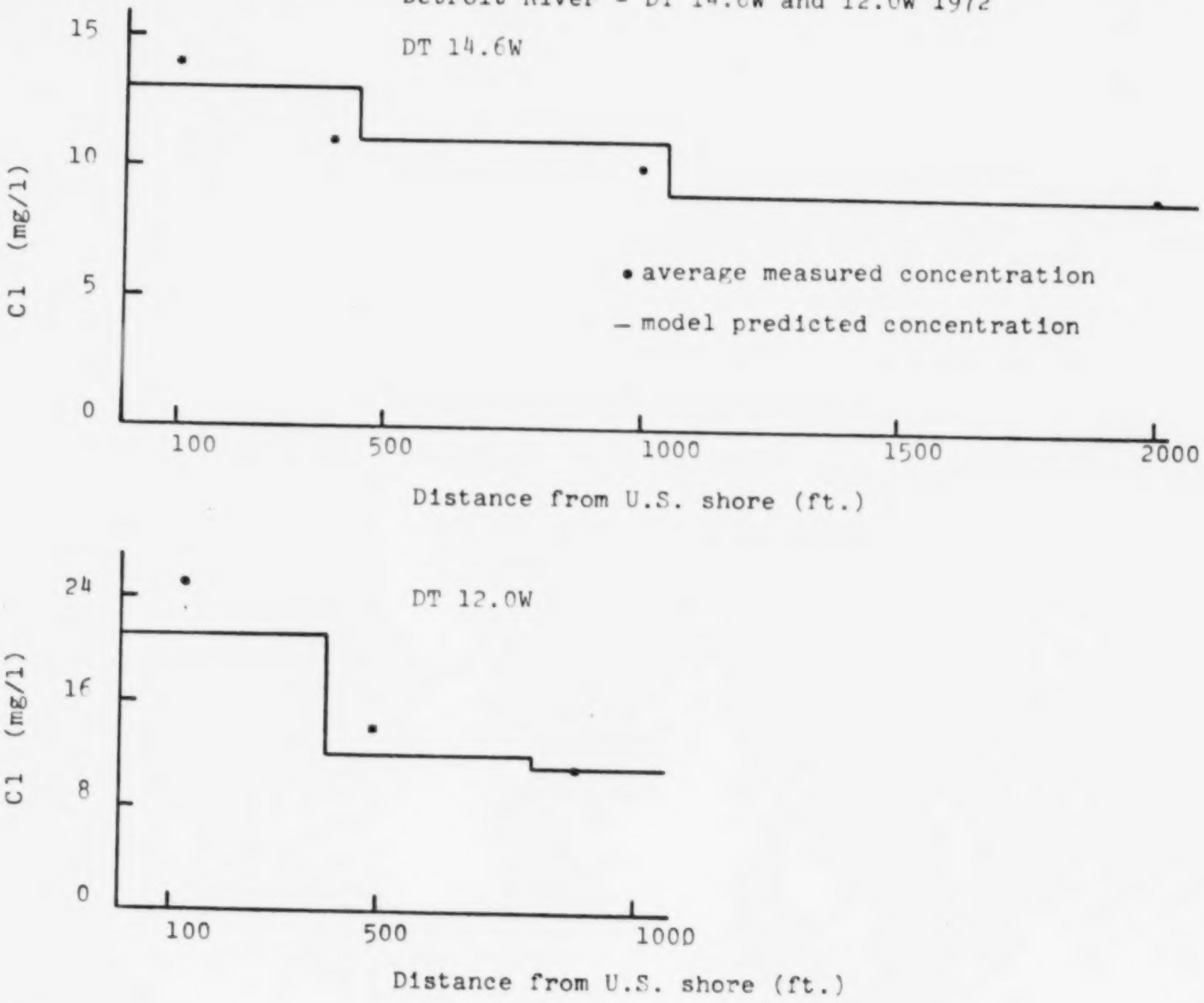
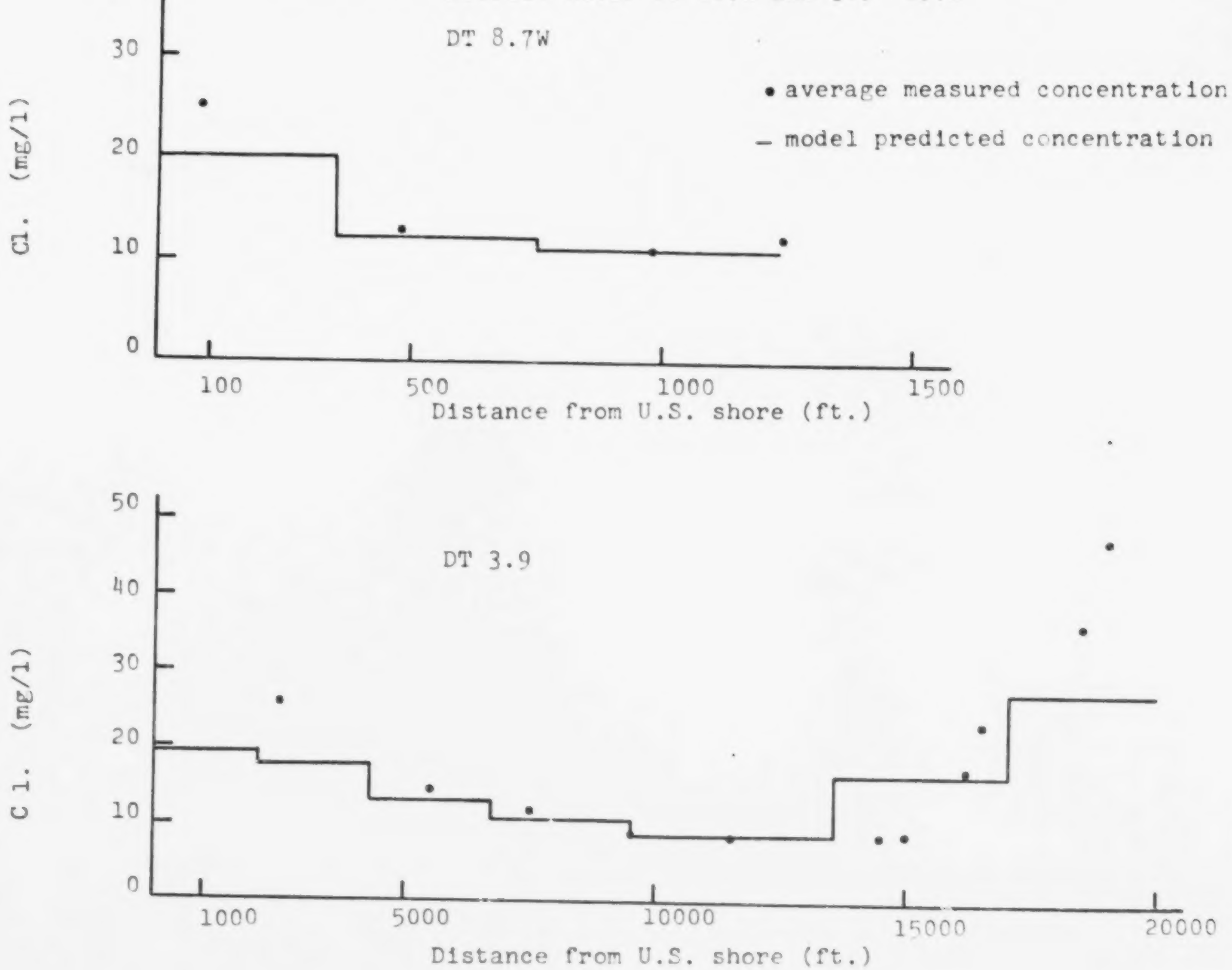


Figure 60. Model verification - chloride
Detroit River DT 8.7W and 3.9 1972



model was used for all of the other parameters to be discussed in this section with no changes in the basic segmentation or dispersion coefficients.

It should be mentioned here that all discussion has centered on the United States shore and center sections of the river. At the time of verification, Canadian loading information for the Canadian shoreline was not available. Thus the model at this time has only been verified for the United States side of the river.

Water quality data for 1973 was received from the Ontario Ministry of the Environment. Examination of this data and preliminary runs using the model indicated three major sources of chloride loading to the river. These areas were defined as: near the Canadian Rock Salt Company Ltd., near the waste beds at the south end of Fighting Island, and in the Amherstburg Channel near Amherstburg, Ontario. Preliminary estimates for these loads were made and the results of the model compared favorably with water quality data. However, these are only preliminary results and must be supported by additional loading and water quality data. It is hoped that this can be accomplished in the near future so that a fully verified model for the entire river can be made available.

Phenol

Industrial survey data for the years 1963, 1968, 1969, 1972, and 1973 indicated that the following industries were discharging phenol: Allied Chemical, Great Lakes Steel, Pennwalt Chemicals, McLouth Steel and Mobil Oil. The Detroit Wastewater Treatment Plant and the Rouge River were also sources of phenol loadings to the river.

Phenol is normally considered a non-conservative substance in an aquatic system. However, the time of passage in the lower Detroit River from Zug Island to Lake Erie is very short (12 hours). Therefore, it was assumed that any degradation of phenol due to biological activity would probably be small, and treating phenol as conservative substance (k=0) would be reasonable for this river system. As can be seen in the results, the assumption proved to be adequate for most sections of the river.

The results for various years at selected stations are shown in Figures 61-67. A complete listing of model outputs and loadings for the river is given in Appendix D. The initial verification runs showed good correlation between model results and field data. In each case, the model predicted increase in phenol concentration below a discharge point compared closely with the increase measured in the field. However, at two milepoints

Figure 61 . Model verification - phenol
Detroit River - DT 17.4 W and 14.6W 1968

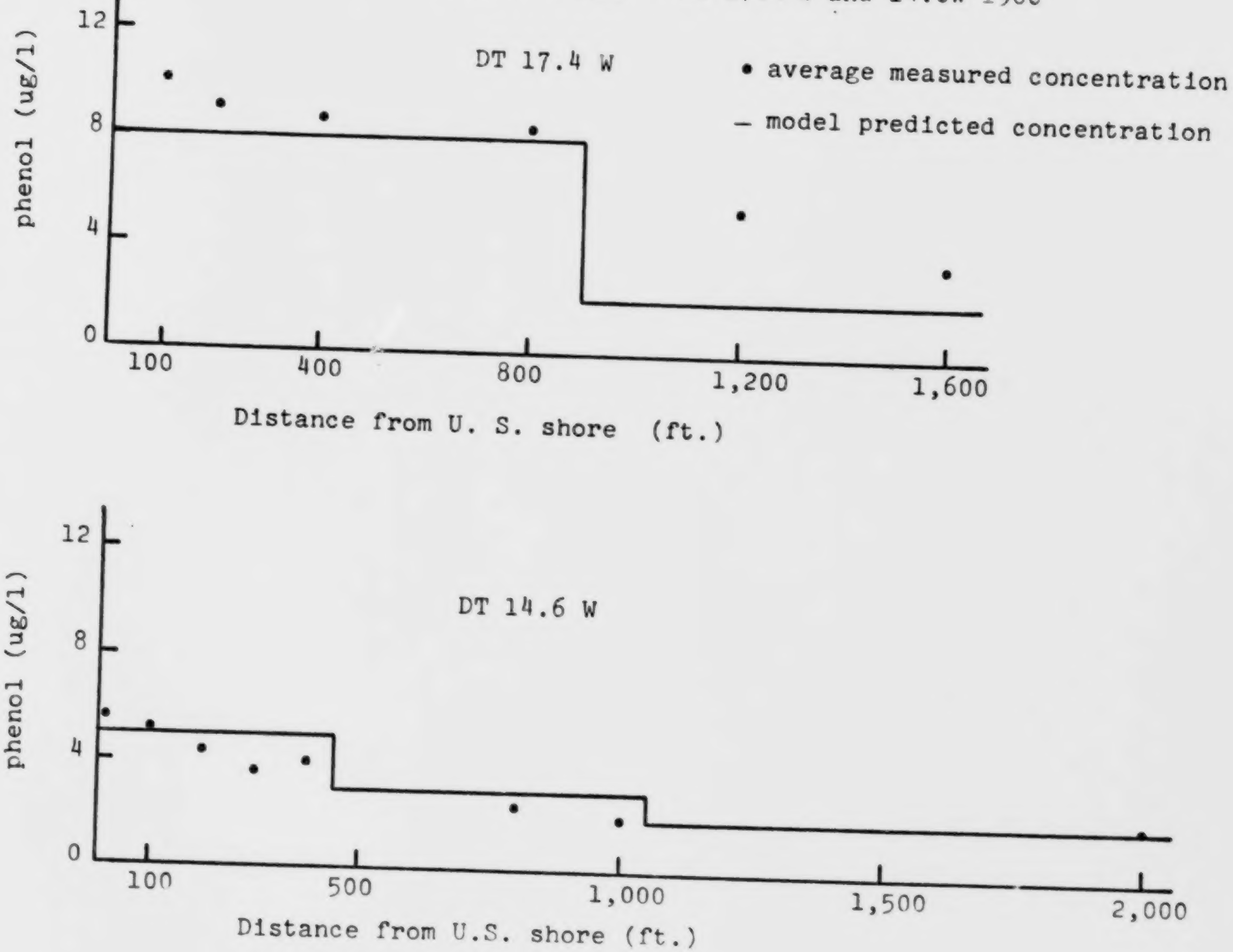


Figure 62 . Model verification - phenol
Detroit River - DT 12.0 W and 8.7W 1968

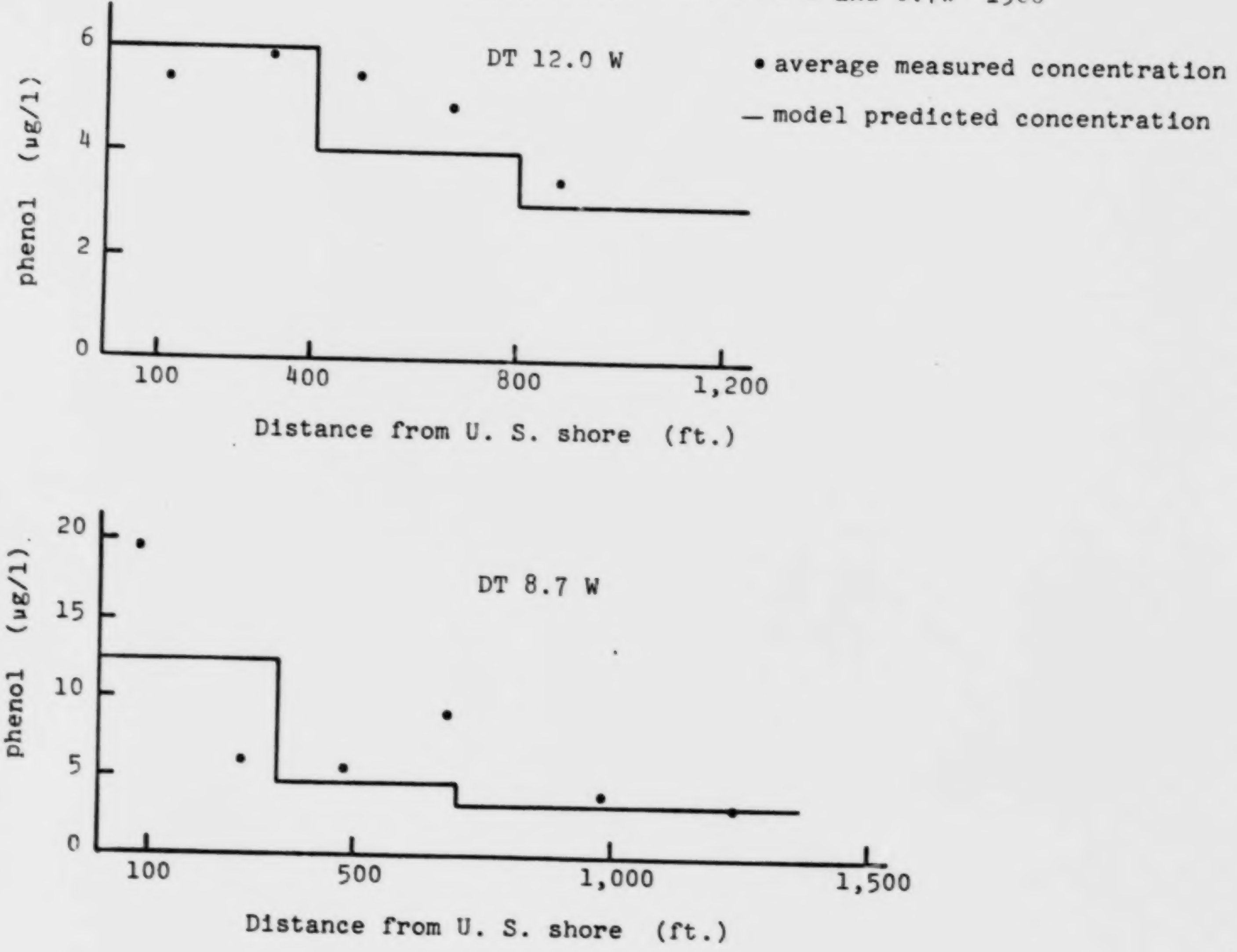


Figure 63 . Model verification - phenol
Detroit River - DT 3.9 - 1968

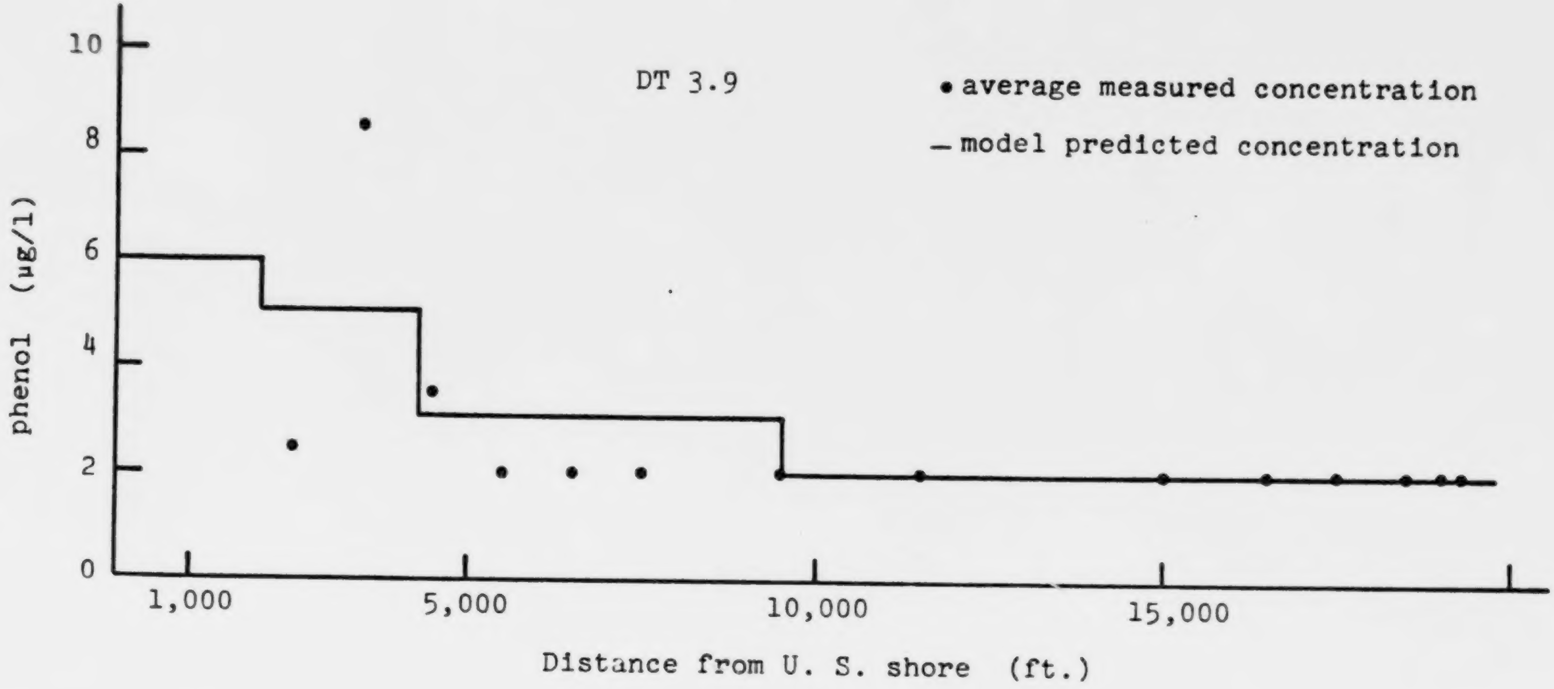


Figure 64 . Model verification - phenol
Detroit River - DT 17.4 W and 14.6 W 1969

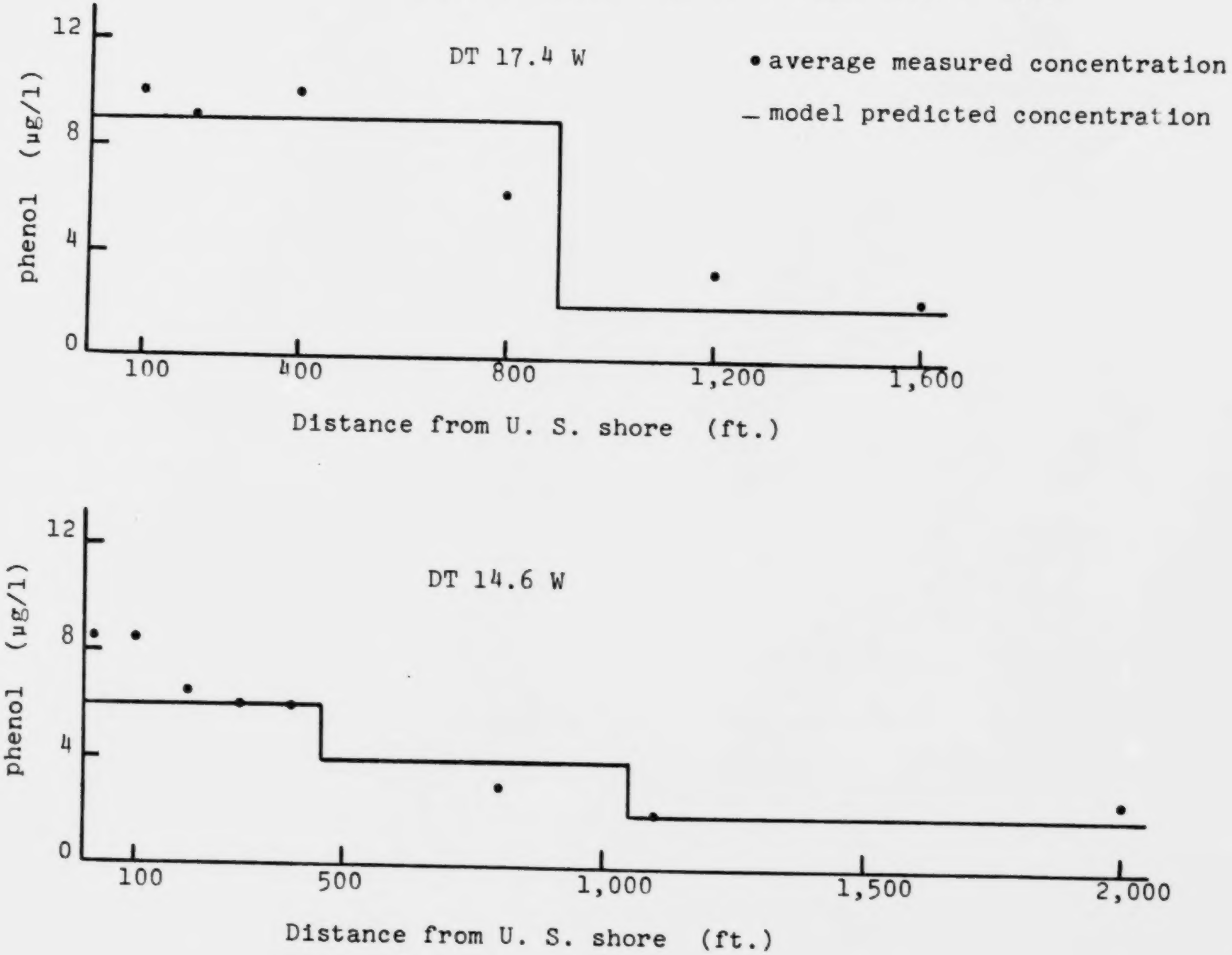


Figure 65 . Model verification - phenol
Detroit River - DT 12.0 W and 8.7W 1969

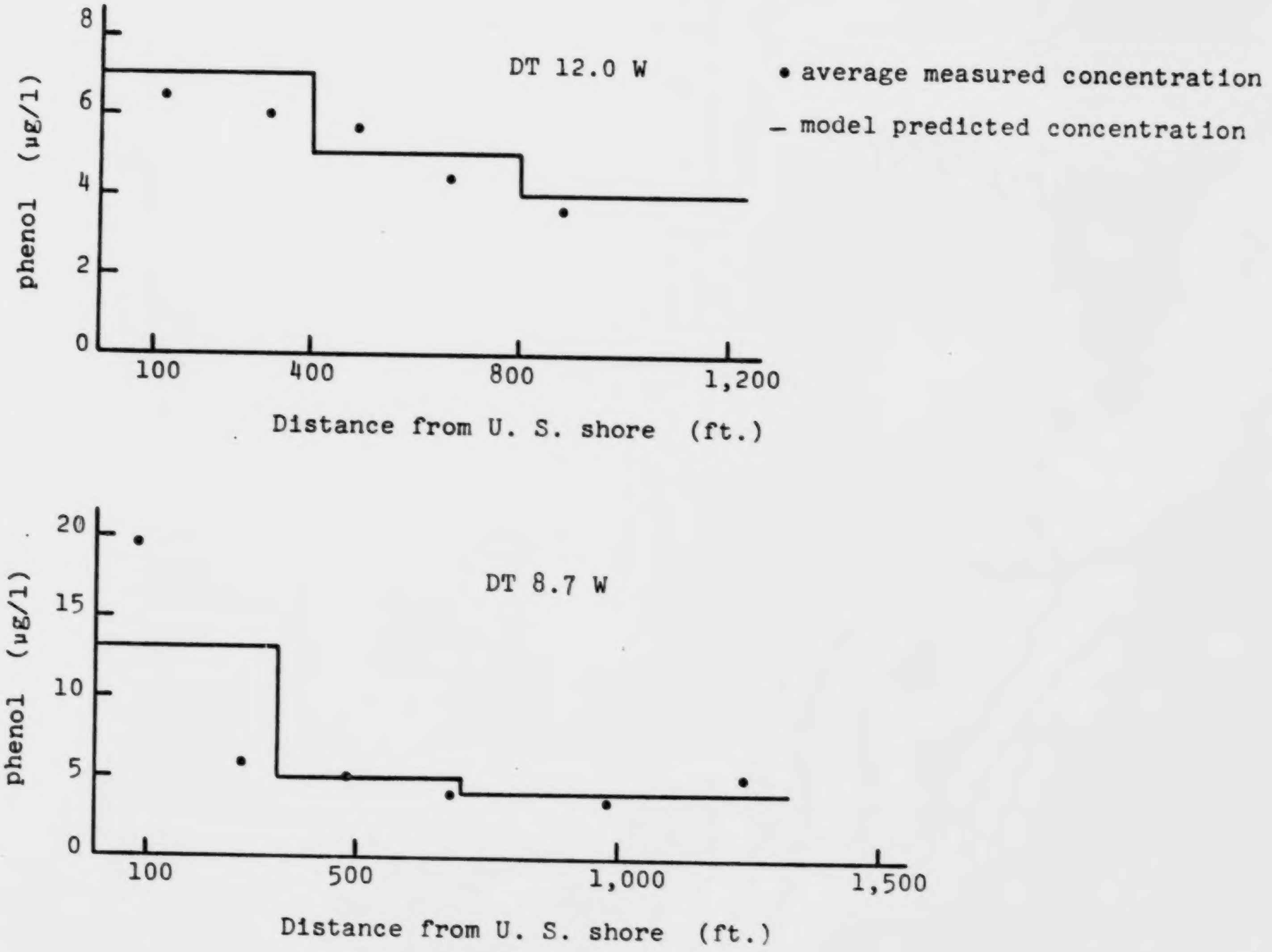


Figure 66 . Model verification - phenol
Detroit River - DT 19.0 and 14.6W- 1972

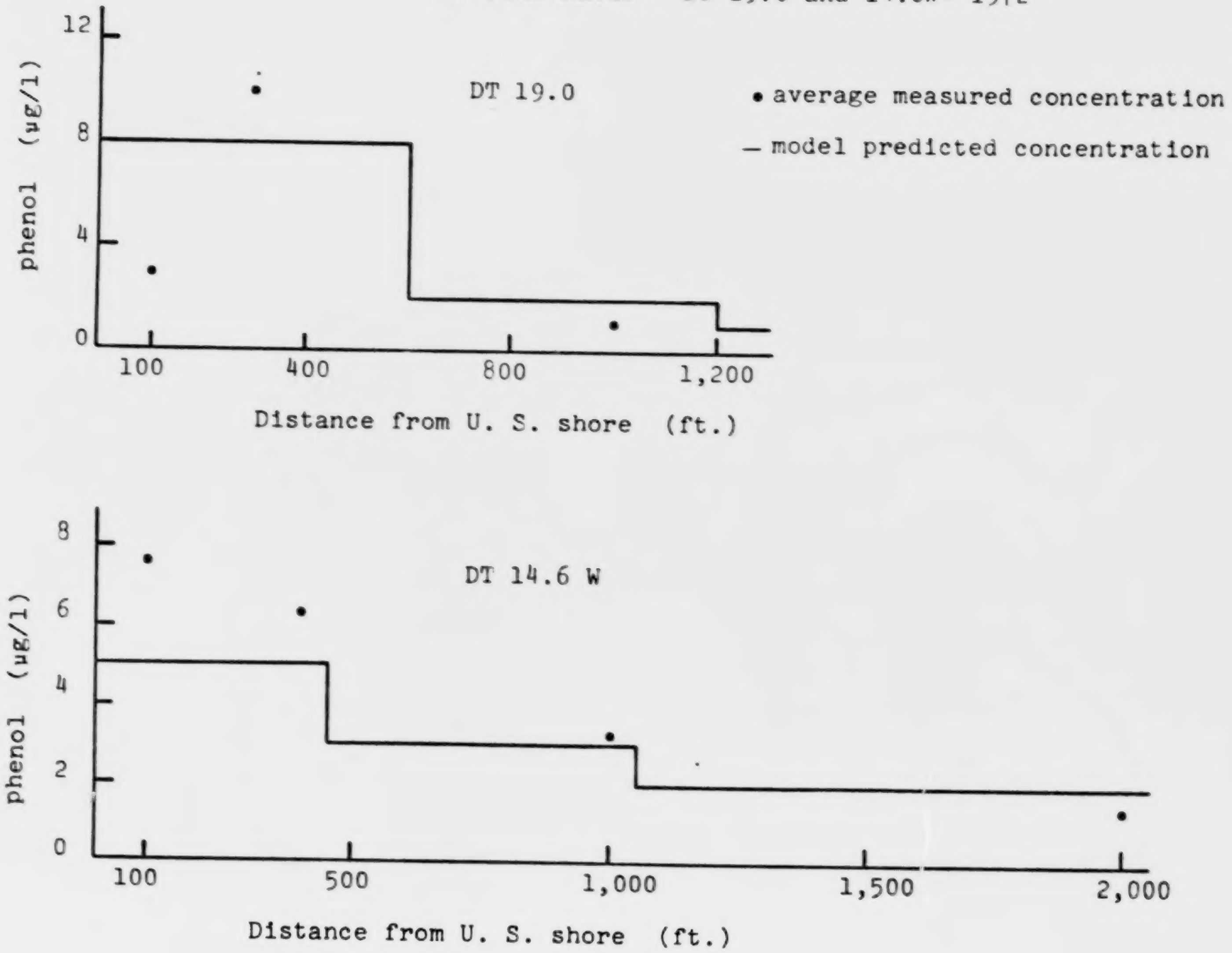
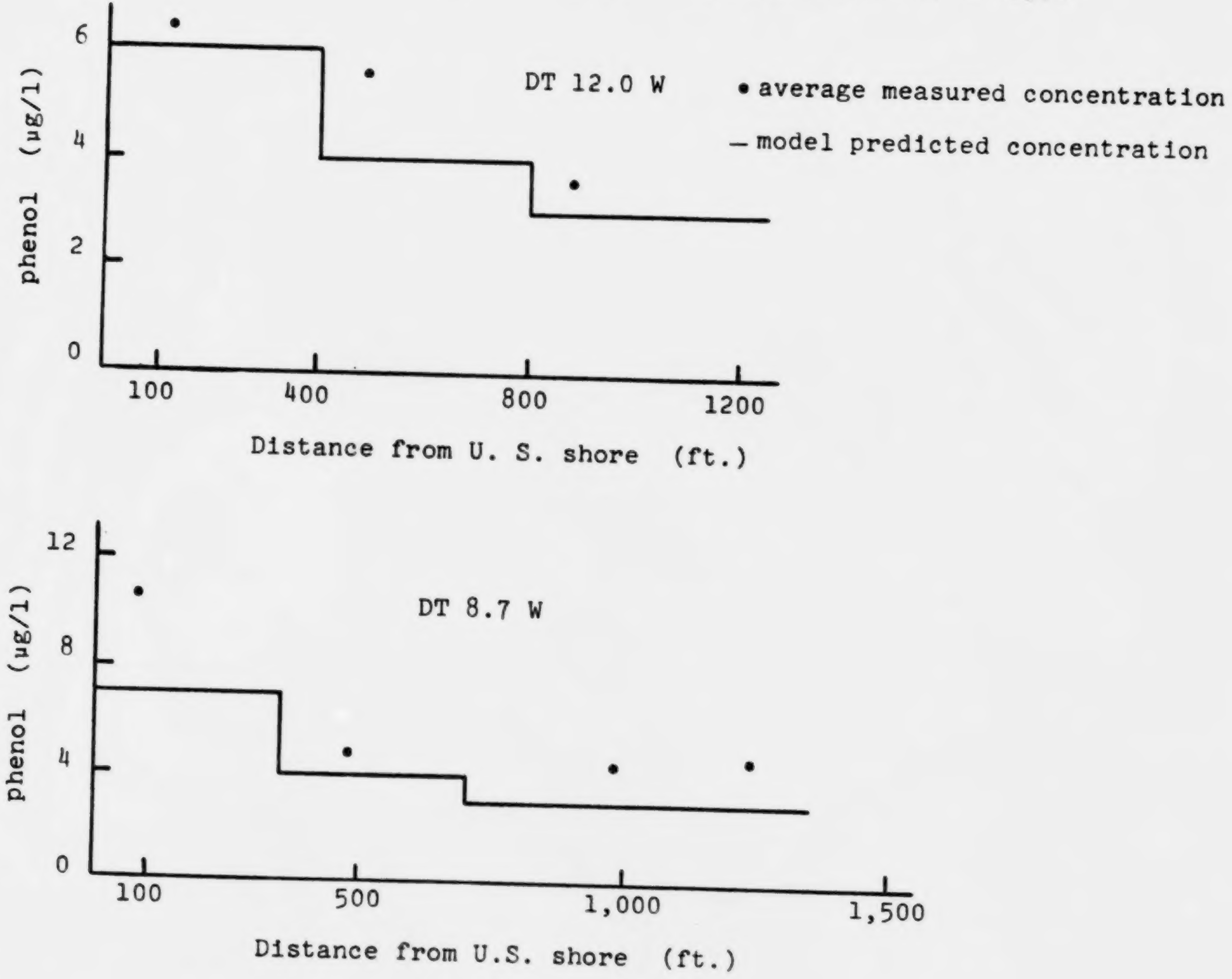


Figure 67 . Model verification - phenol
Detroit River - DT 12.0 W and 8.7 W 1972



(14.6W and 3.9) the model predicted levels were much higher than the measured concentrations.

An examination of the measured phenol concentrations at milepoints 17.4W and 14.6W (see Figure 61 and 64) shows that a considerable drop in phenol levels occurs between these two stations. At the present time there is no documented evidence as to exact nature of the phenol "sink". There is some information that indicates a sorption-sedimentation process may be responsible for the drop in concentration. This section of the river (between 17.4 and 14.6) is wider and shallower than the immediate upstream sections, and river velocities appear to be slower. The Detroit Wastewater Treatment Plant, and the Rouge River and Great Lakes Steel are all located just above milepoint 17.4W. Each of these are sources of suspended solids, iron, and other heavy metals, in addition to phenol. In analyzing the iron data for this section of the river, it can be seen that iron concentrations follow a pattern similar to the phenol levels. The iron concentrations decrease considerably through this section of the river. Core samples taken during the survey program also indicated an increase of iron and other heavy metals in the sediment in this area. A more detailed discussion of the sediment condition is given in the chemistry section of this report.

A similar drop in phenol concentration also occurred between milepoints 8.7W and 3.9. The decrease in this area was much less than at the upstream sections but river conditions and sediment samples were similar in both cases.

In order to simulate these decreases in phenol concentrations, negative loads were introduced for those segments of the model located in the areas discussed above (between 17.4W and 14.6W and between 8.7W and 3.9). A listing of the negative loads used in given in Table 31. At the present time the choice of appropriate negative loads is an empirical process. However, in the future, as more information becomes available in these critical areas, it may be possible to develop a mathematical relationship to define these processes. This relationship could then be incorporated into the model, and based on the appropriate input parameters, the model could be used to predict the decreased concentrations in these areas.

Iron

The program for simulating iron concentrations in the river followed the same general pattern as for chloride and phenol. Loading information was obtained from survey data

Table 31 . NEGATIVE LOADS FOR MODEL - PHENOL AND IRON - DETROIT RIVER

Area of river mile points	Model segment	1963 #/day	1968 #/day	1969 #/day	1972 #/day	1973 #/day
	Phenol					
17.4 W - 14.6 W	23	200	400	200	300	300
	30	400	650	400	500	500
8.7 W - 3.9	60	600	200	200	100	100
	61	600	200	200	200	200
	Iron					
17.4 W - 14.6 W	23	-	60000	50000	40000	40000
	30	-	100000	100000	80000	80000

which indicated Great Lakes Steel, McLouth Steel, Firestone Tire and Rubber, the Detroit Wastewater Treatment Plant, Wayne County Wastewater Treatment Plant and the Rouge River as sources of iron input to the river. Iron was considered a conservative substance for all areas of the river.

A comparison of the model predicted levels versus field data for several stations is given in Figures 68-73. As in the case of phenol, the results were quite good except at milepoint 14.6W. The drop in iron concentration between 17.4W and 14.6W paralleled the drop in the phenol concentrations. This phenomenon was handled in the same manner as phenol. The negative loads used for iron are given in Table 31.

Ammonia

The Public Health Service Study[6] indicated that the major input of ammonia-nitrogen to the river was the Detroit Waste Treatment Plant. The Detroit Plant has not monitored ammonia levels in the effluent during past years, and consequently, the only data found was from the 1963 Public Health Service Study. Assuming the ammonia-nitrogen concentration (8.0 mg/l NH_3 -N) has remained relatively constant, and using flow data measured at the plant, it was possible to estimate the loading levels for several years. These estimated values, along with measured loadings from other sources (see Appendix D), were used in the model. As in the case of phenol, ammonia nitrogen was assumed to be a conservative substance for this river system. Because of the short time of passage in the system, the effects of nitrification in the river appear to be small. Several test runs were made to check this assumption. If the oxidation of ammonia is assumed to follow first order kinetics, the model can be used to project the effects of this oxidation on ammonia concentrations. The normal range of the first order reaction coefficient for ammonia is 0.1 to 0.6/day. A value of 0.6/day was used in the model and the results were compared with the output using the conservative asssumption. The difference in concentrations between the two outputs was negligible. Thus the conservative assumption appears to be adequate for this particular river system. The results of the model projections compared with measured levels is given in Figures 74-79. As can be seen, the simulated levels compare quite well with measured levels in the river.

It would appear from this study that the estimated levels for the Detroit Waste Treatment Plant are reasonable. However, these levels should be verified as data becomes available. Detroit personnel have indicated that ammonia concentrations will be monitored on a routine basis in the near future. As this information becomes available, the assumptions

Figure 58. Model verification total iron
Detroit River DT 17.4W and 14.6W 1968

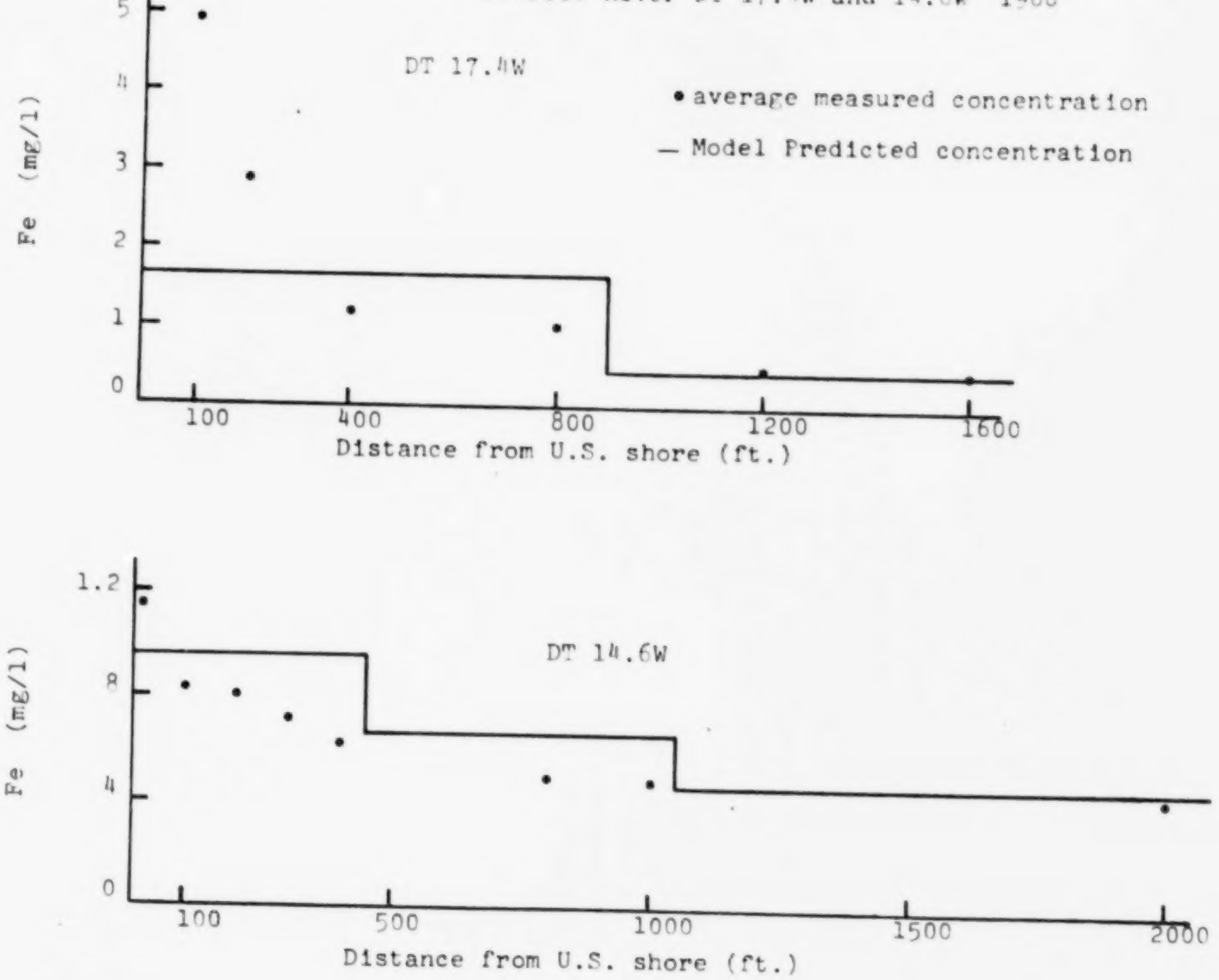


Figure 69. Model verification total iron
Detroit River DT 12.0W and 8.7W 1968

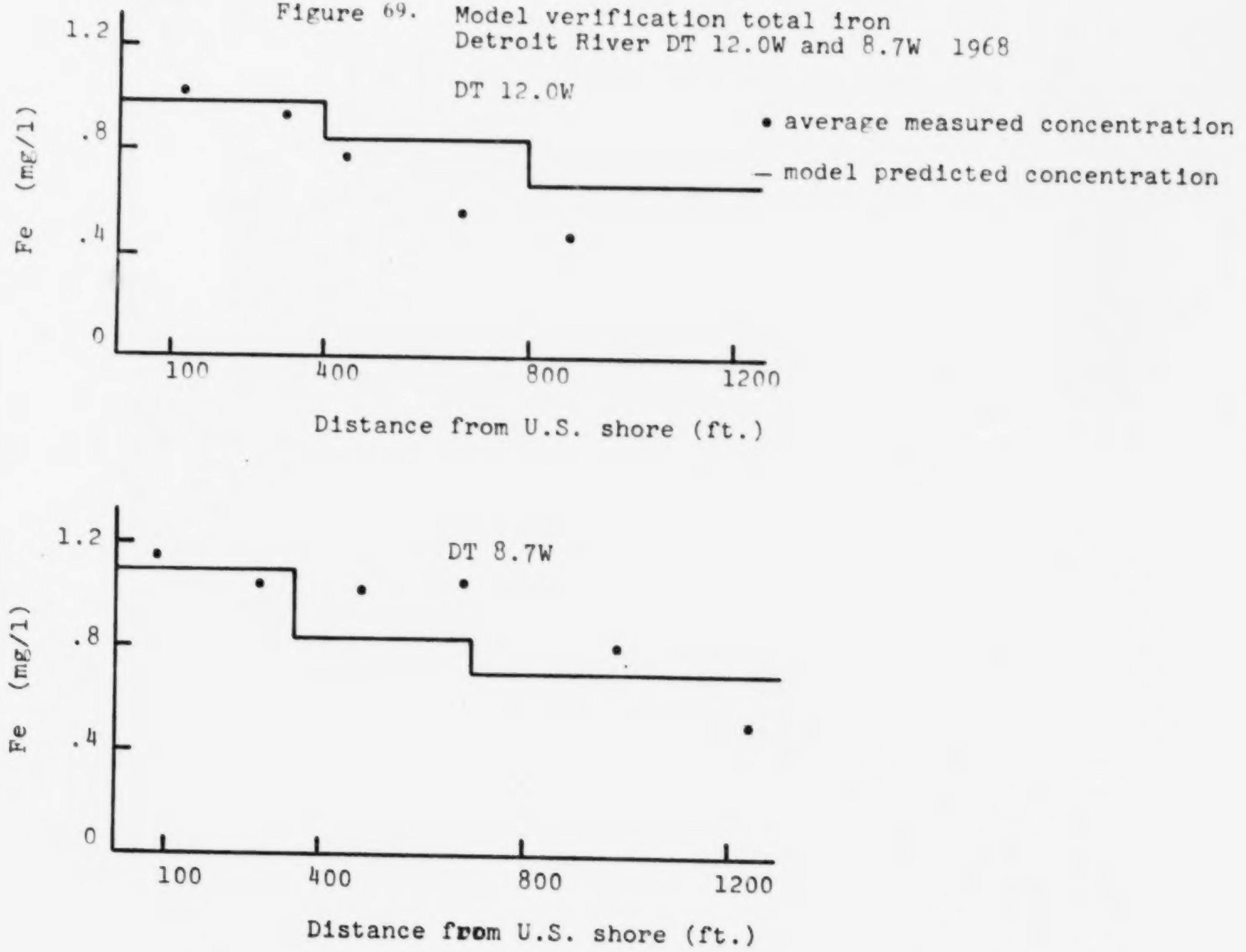


Figure 70. Model Verification total iron
Detroit River DT 3.9 1968

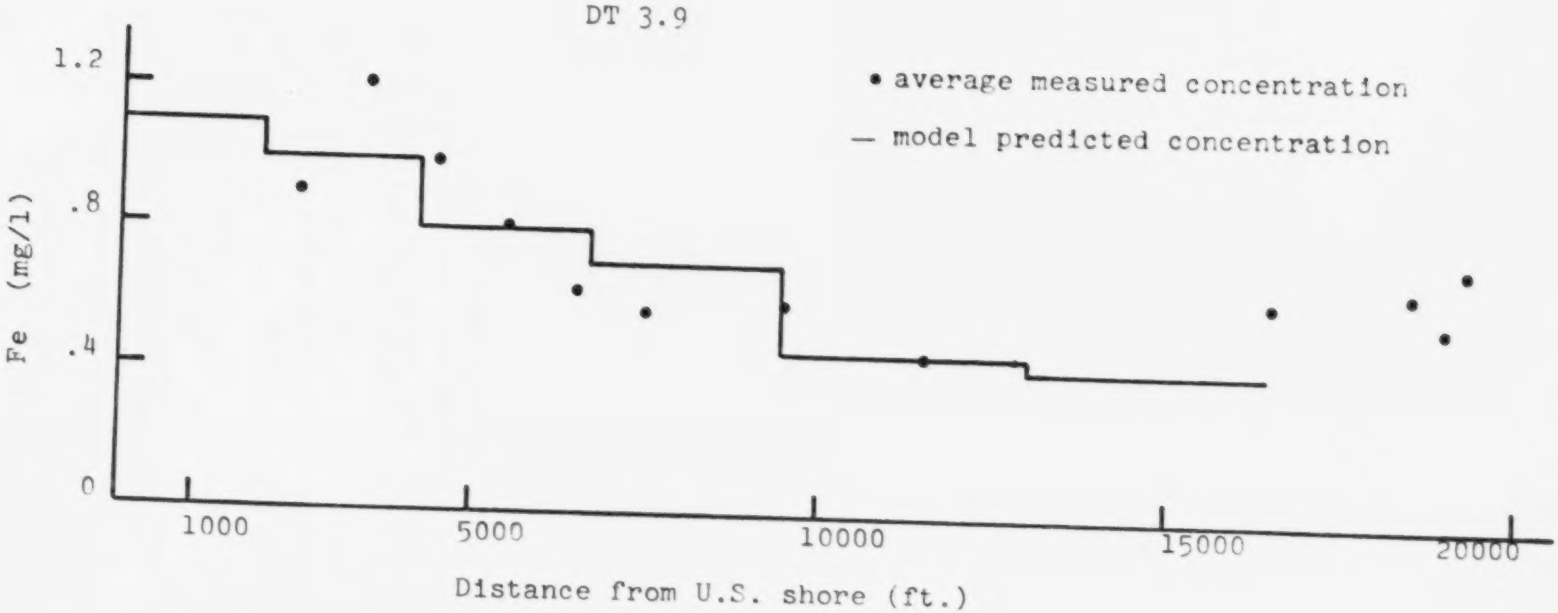


Figure 71. Model verification total iron
Detroit River DT 17.4W and 14.6W 1969

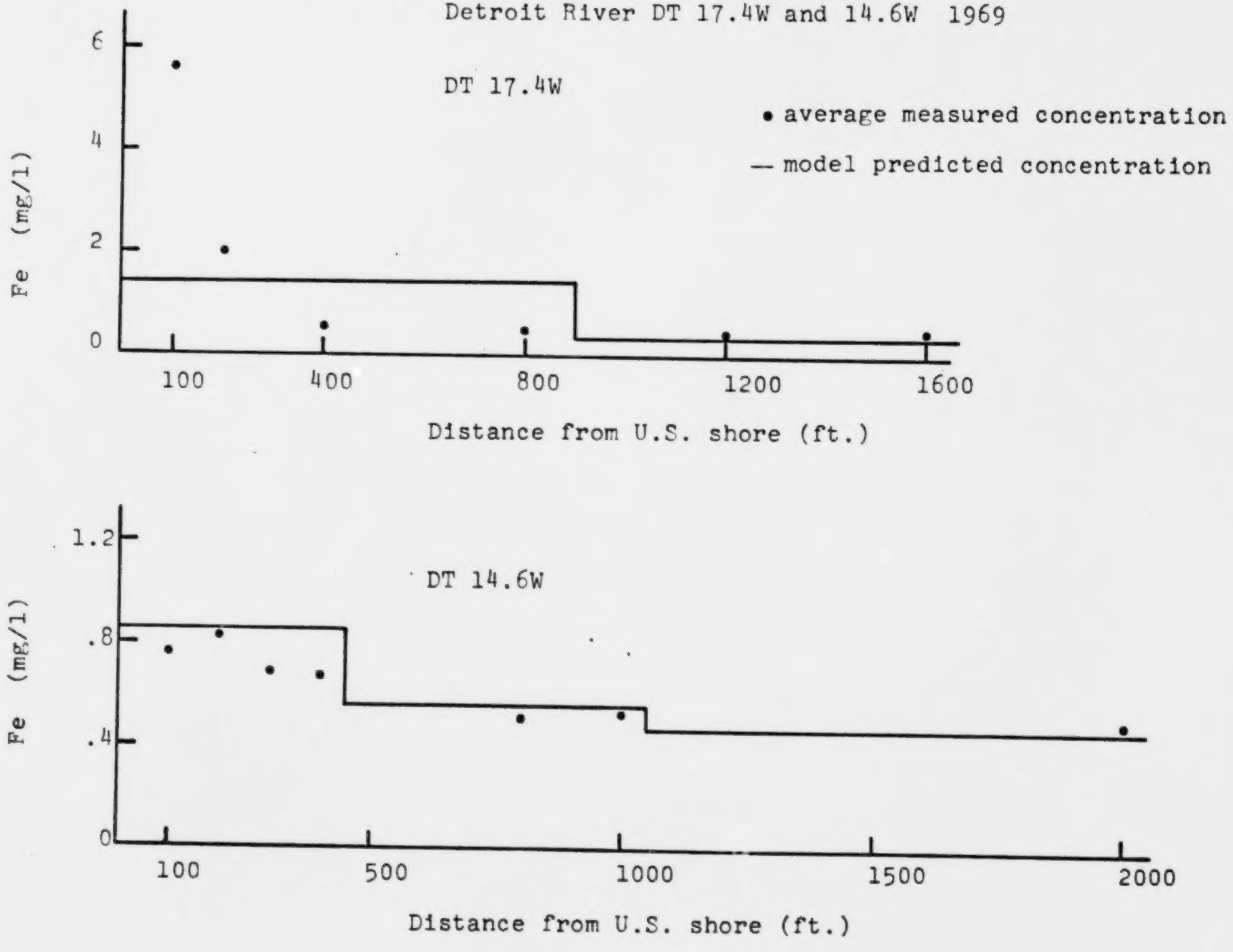
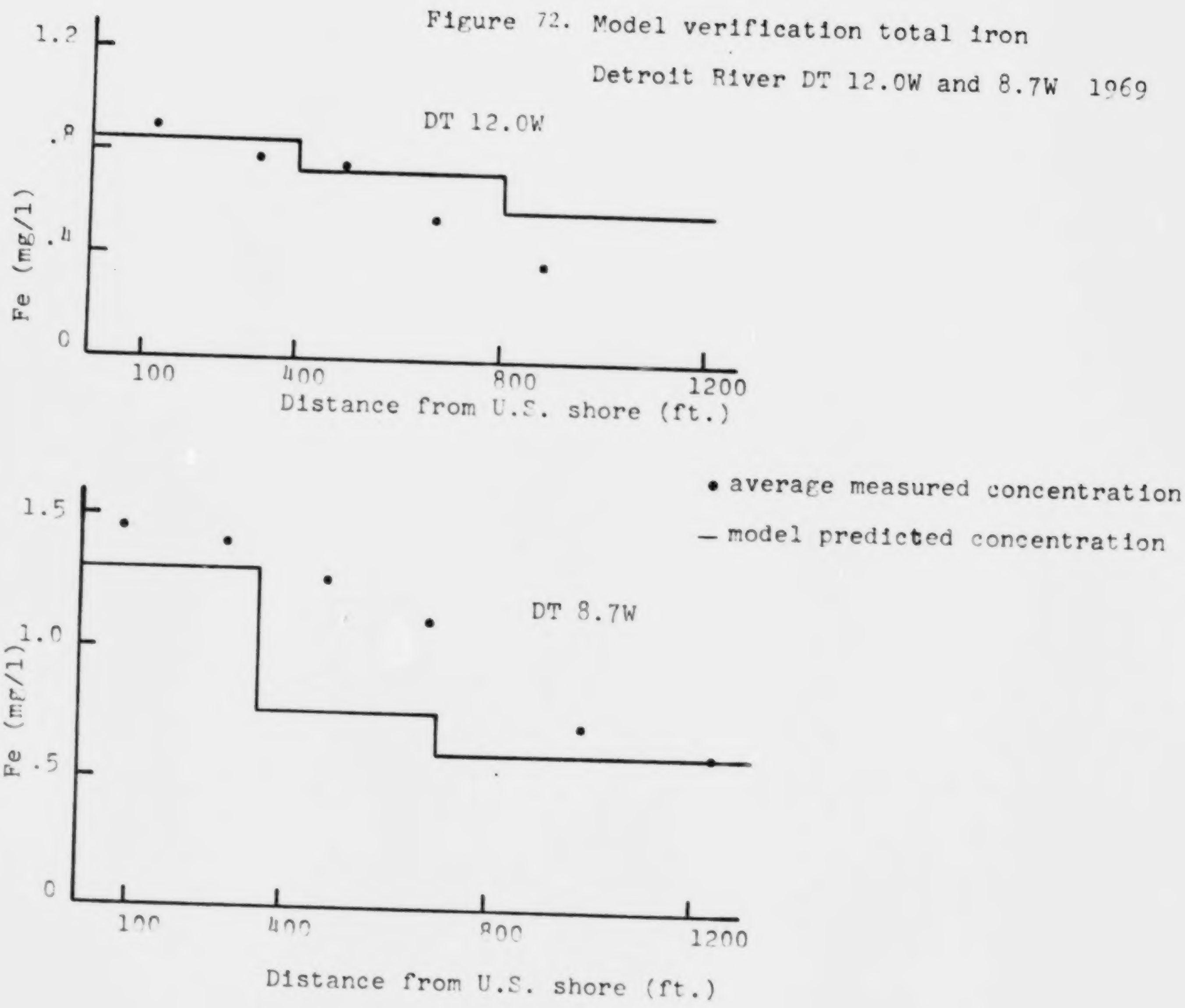


Figure 72. Model verification total iron

Detroit River DT 12.0W and 8.7W 1969



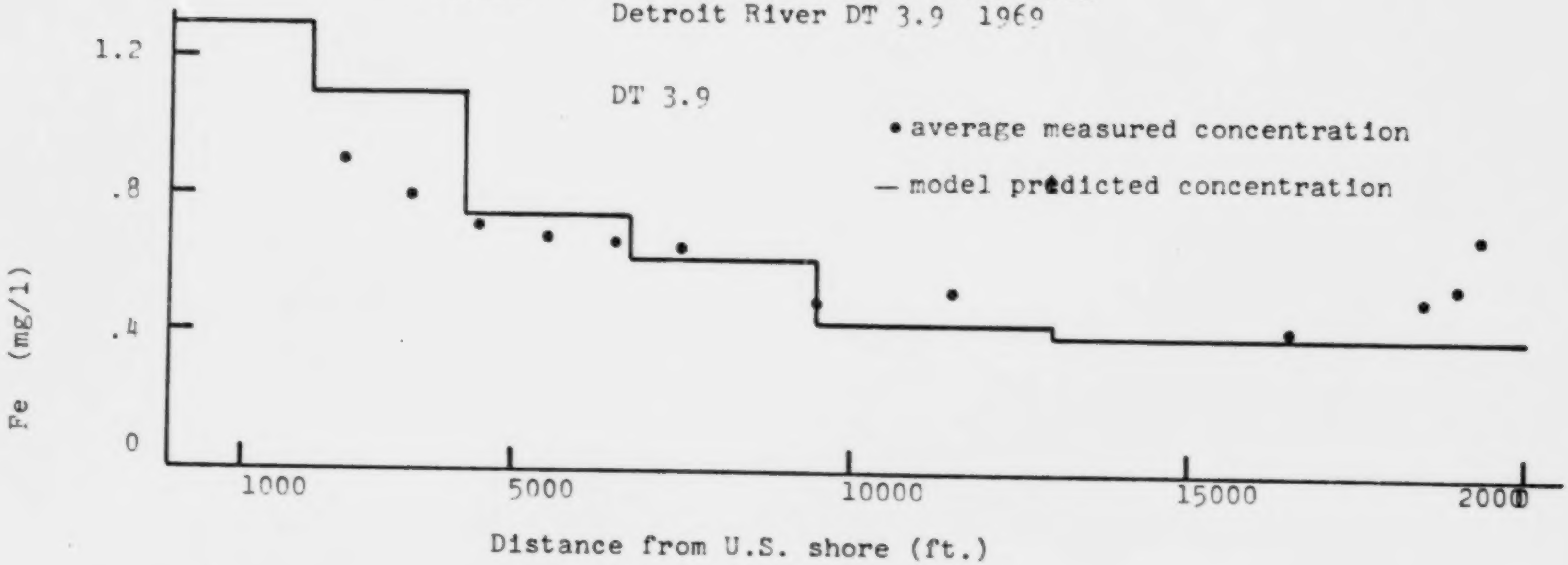


Figure 73 Model verification total iron
Detroit River DT 3.9 1969

Figure 74. Model Verification - Ammonia Nitrogen Detroit River - DT 19.0 and 14.6 W - 1972

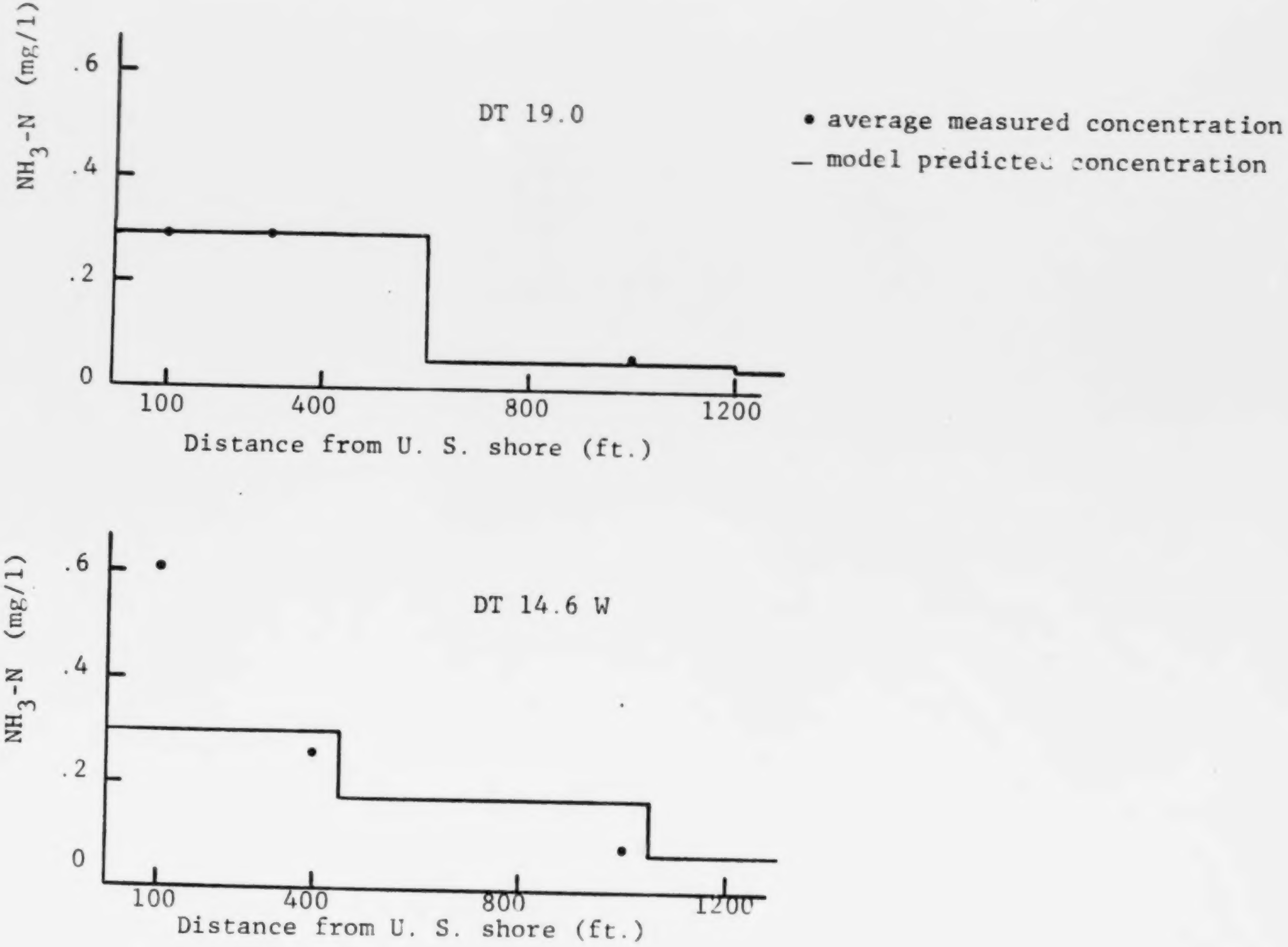


Figure 75 . Model verirication - ammonia nitrogen Detroit River - DT 12.0W and 8.7W 1972

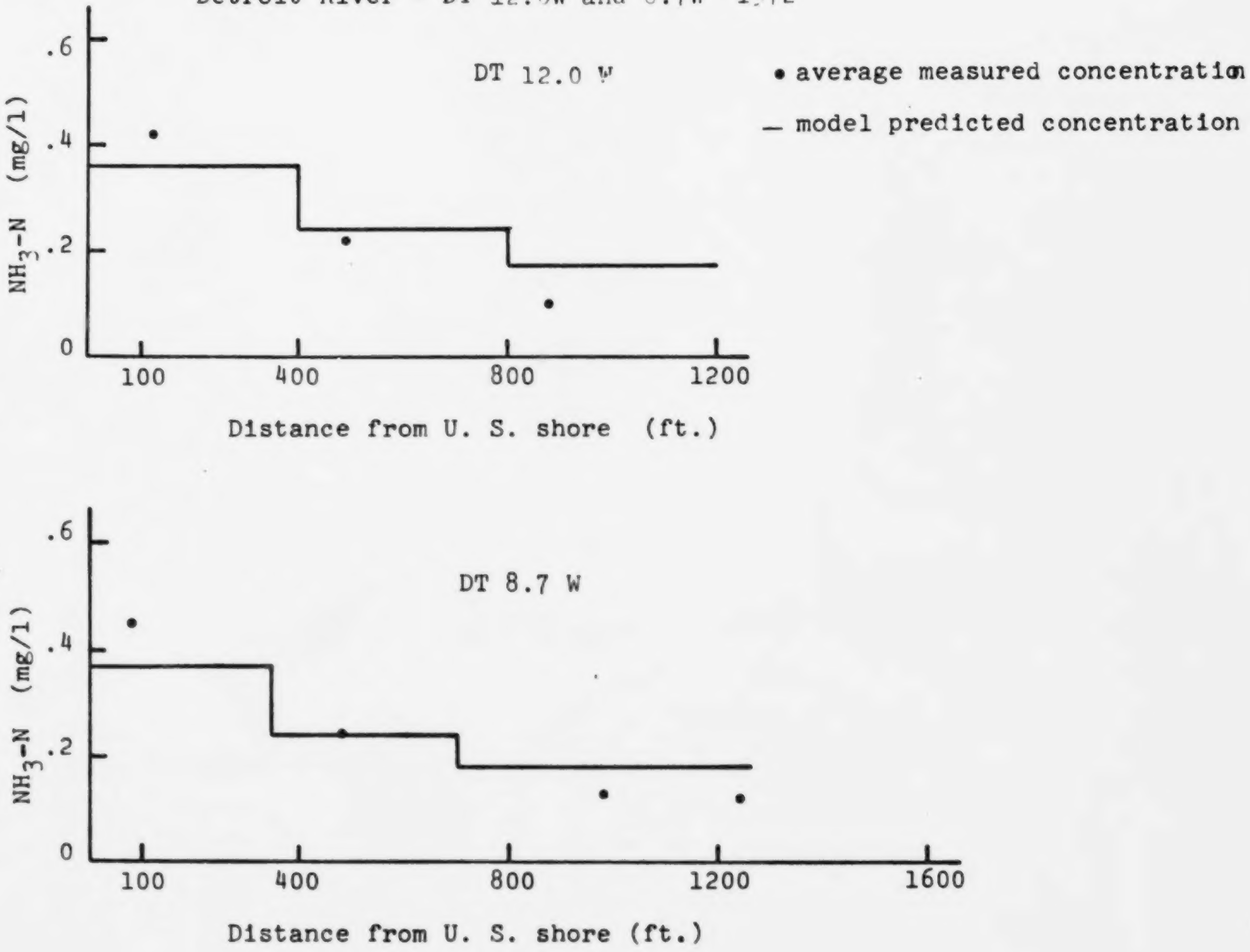


Figure 76 . Model verification - ammonia nitrogen
Detroit River - DT 3.9 - 1972

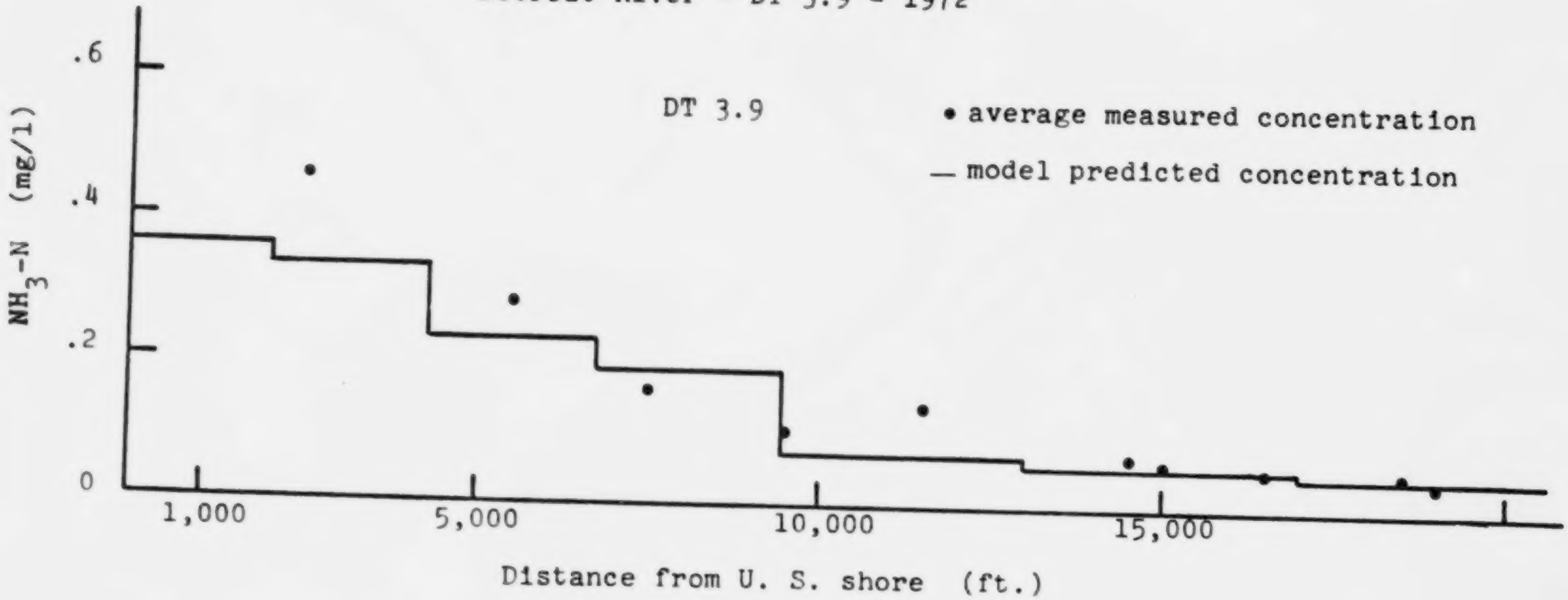


Figure 77 . Model verification - ammonia nitrogen
Detroit River - DT 19.0 and 14.6W- 1973

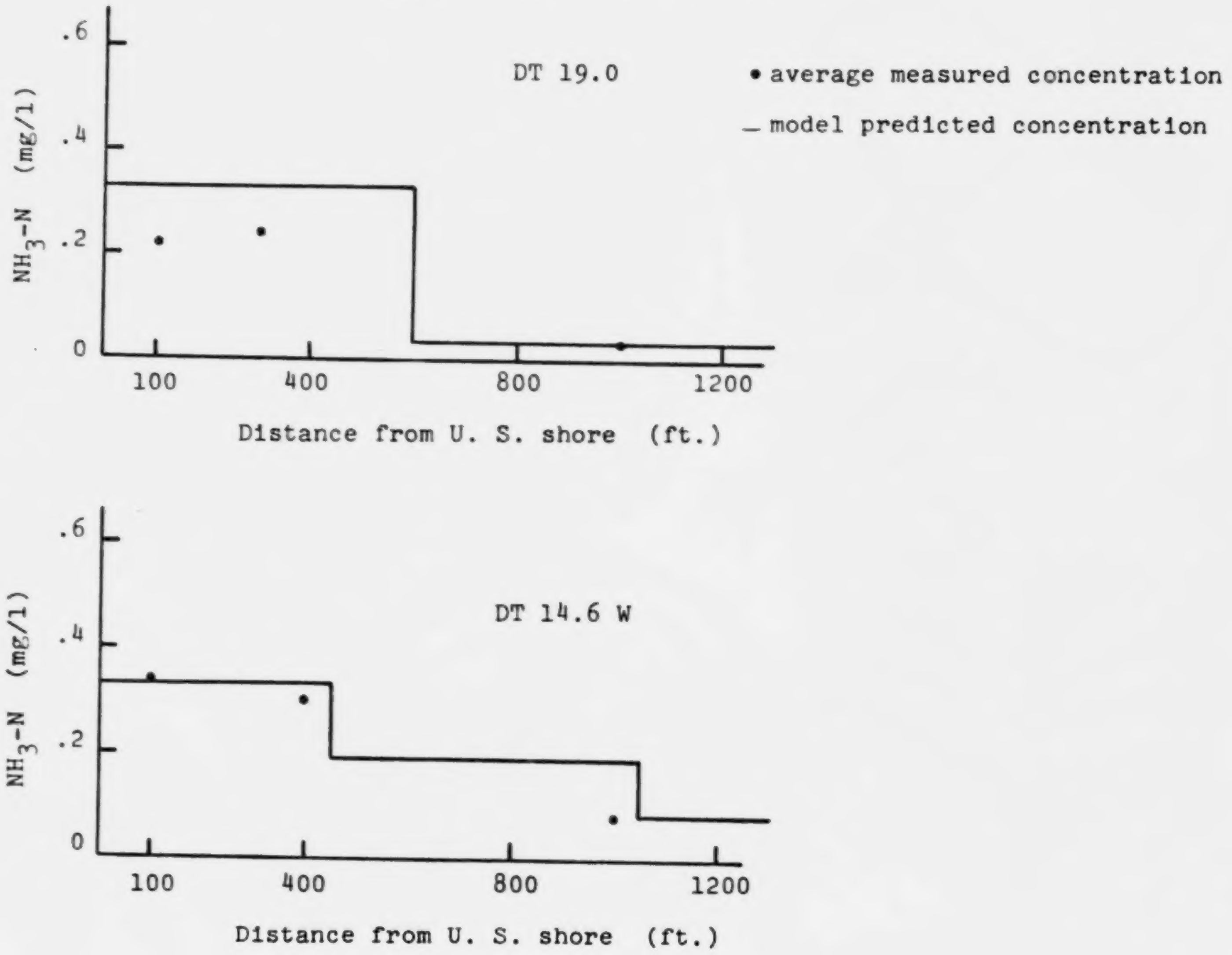


Figure 78 . Model verification - ammonia nitrogen
Detroit River - DT 12.0 W and 8.7W 1973

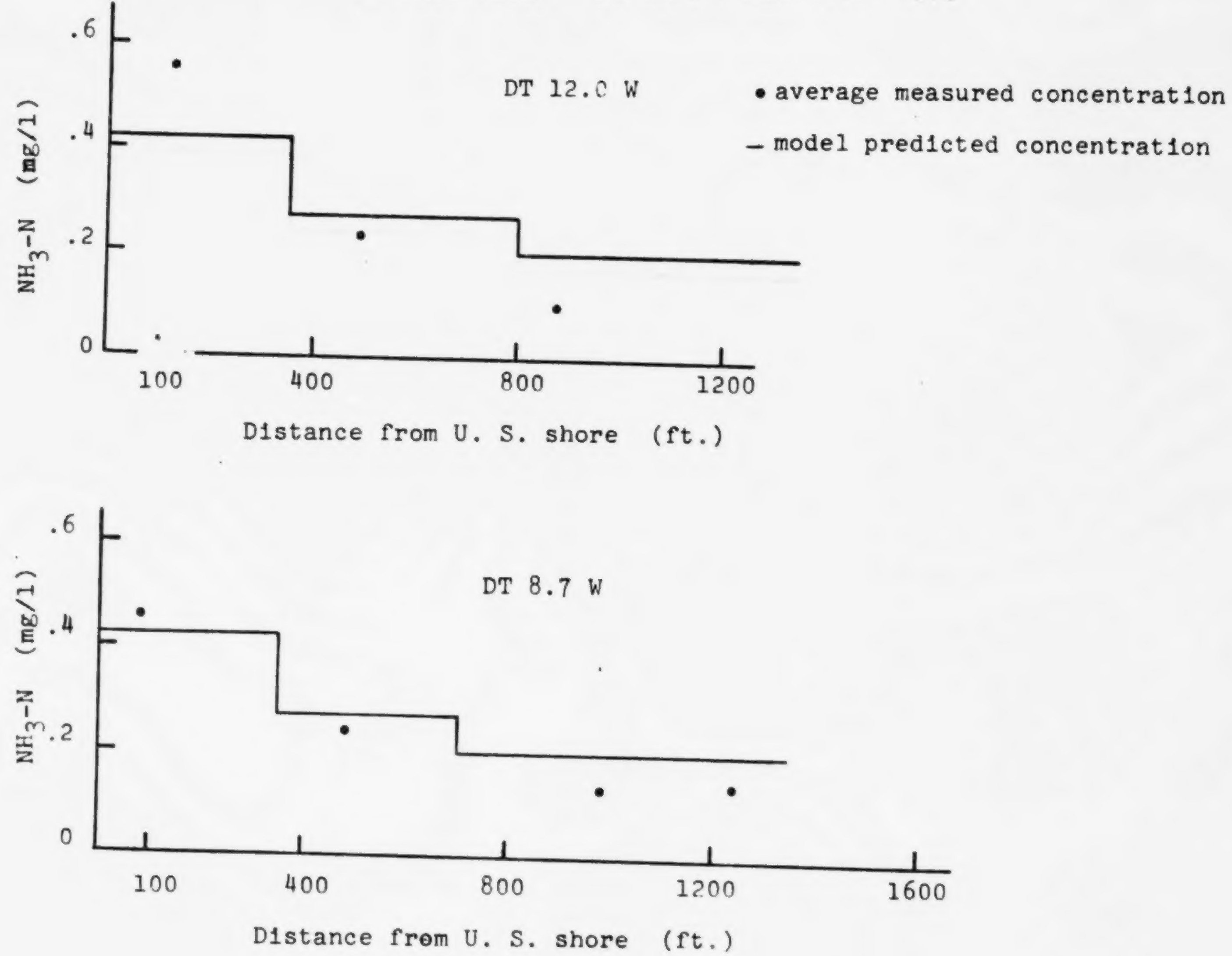
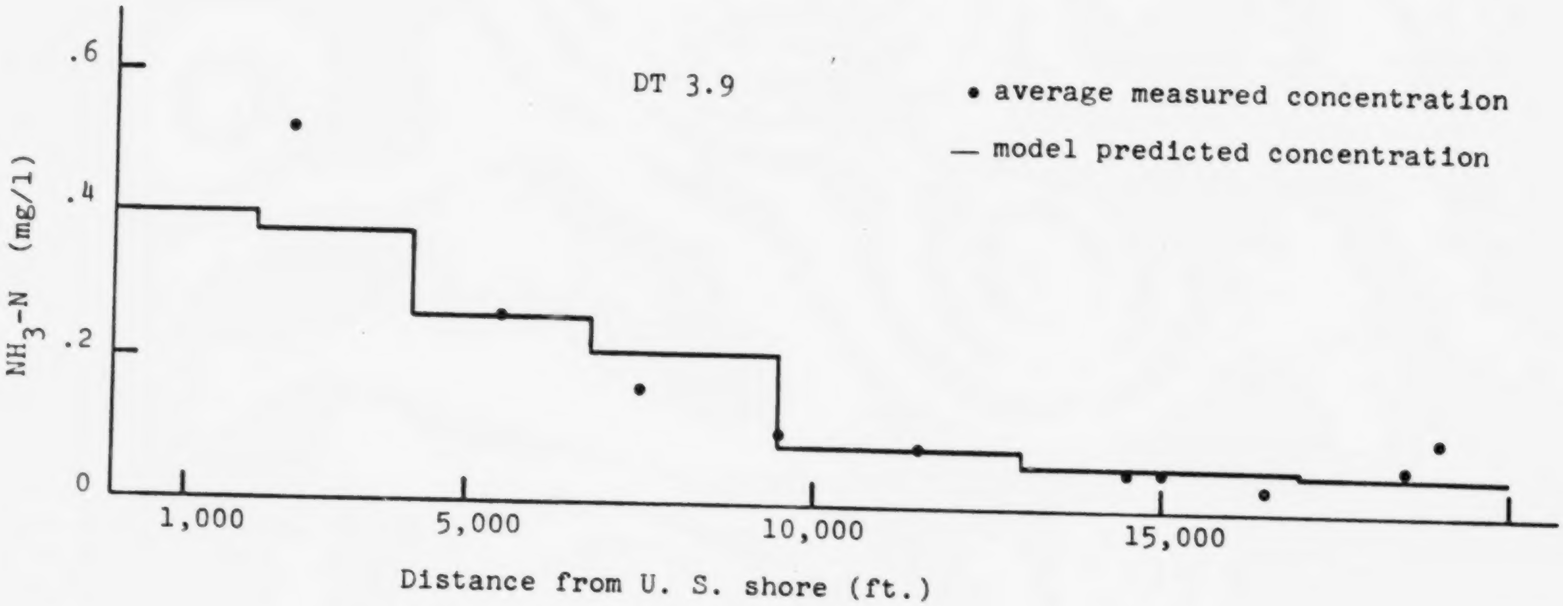


Figure 79 . Model verification - ammonia nitrogen
Detroit River - DT 3.9 - 1973



made during these phases of the modeling programs should be checked and documented. The model should be run using measured ammonia concentrations and checked with data generated by the river monitoring network.

Phosphorus

Total phosphorus loading information was available from industrial surveys and municipal treatment plant operating reports. Using this data, and assuming total phosphorus to be a conservative substance, the model was run for the years 1971, 1972, and 1973.

The results of these runs are presented in Figures 80-88. Comparisons between model projected levels and measured concentrations were not as good for phosphorus as for the parameters discussed previously. For all stations except milepoint 3.9, the predicted total phosphorus concentrations was higher than measured levels. The largest difference was at milepoint 19.0 just below the Detroit Waste Treatment Plant outfall. At the present time, there does not appear to be a plausible explanation for this difference.

The Detroit Treatment Plant is the major contributor of phosphorus to the river at this time. As such, the phosphorus concentration of all of the downstream segments in the model are influenced greatly by the Detroit load. If the difference between measured and predicted concentrations just below the Detroit Plant can be resolved, it appears that the downstream measured concentrations would agree quite well with the model predictions.

Application

The steady state model developed for the Detroit River has been tested and verified for several parameters. The model is capable of projecting the steady state distribution of parameters such as chlorides, phenol, iron, ammonia and total phosphorous. However, the use of the model as a tool in evaluating the effects of future waste loads depends largely on the judgment and skill of the analyst. A thorough understanding of the basic assumptions inherent in the model development, and recognition of various limitations and problems which occurred during the verification are of the utmost importance when using the model for projection purposes.

The model can be a helpful tool in evaluating alternate plans for the management of the river system. The application of the model for parameters such as chloride is fairly

Figure 80. Model verification total phosphorous Detroit River DT 19.0 and 14.6W 1971

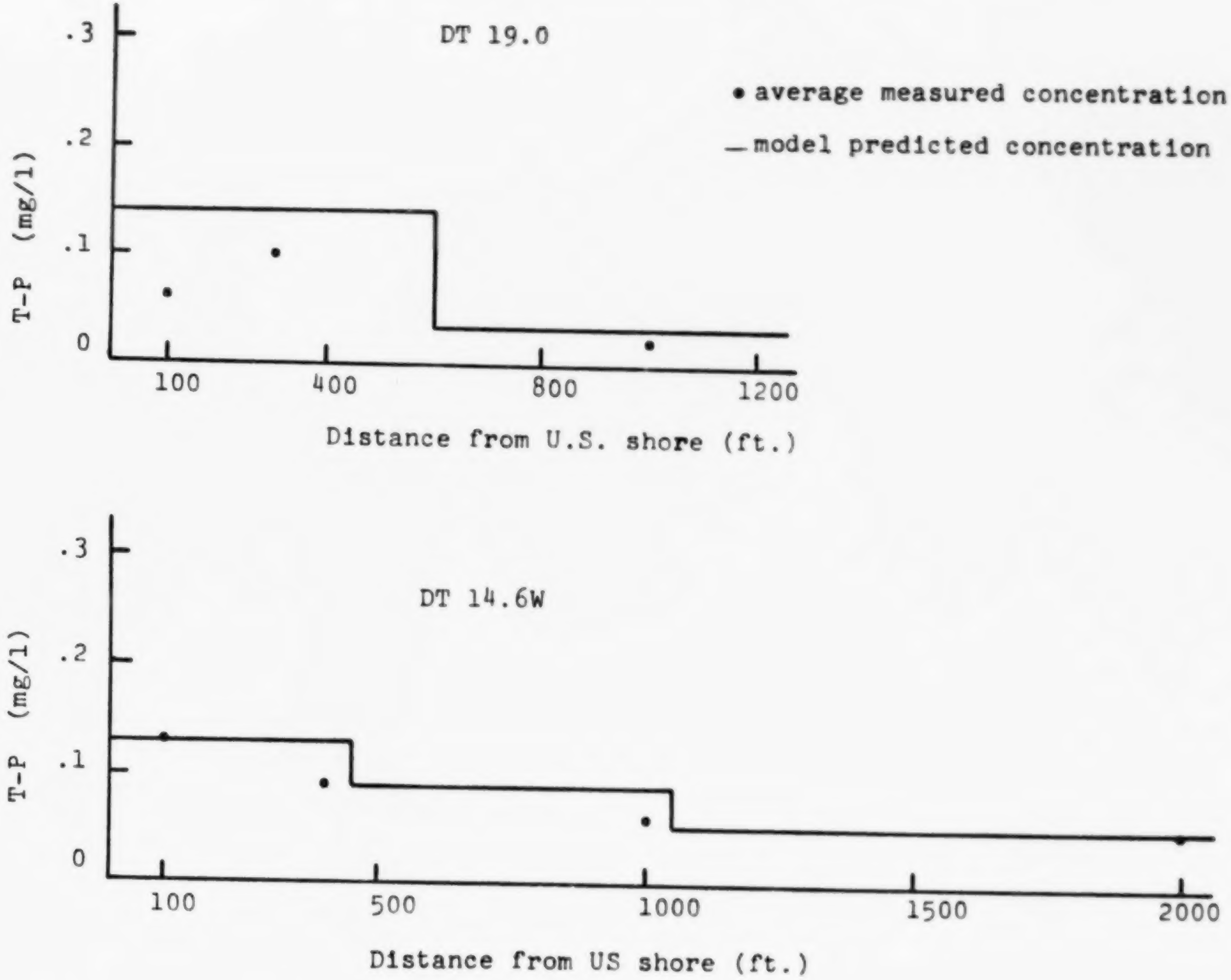


Figure 81. Model verification total phosphorous Detroit River DT 12.0W and 8.7W 1971

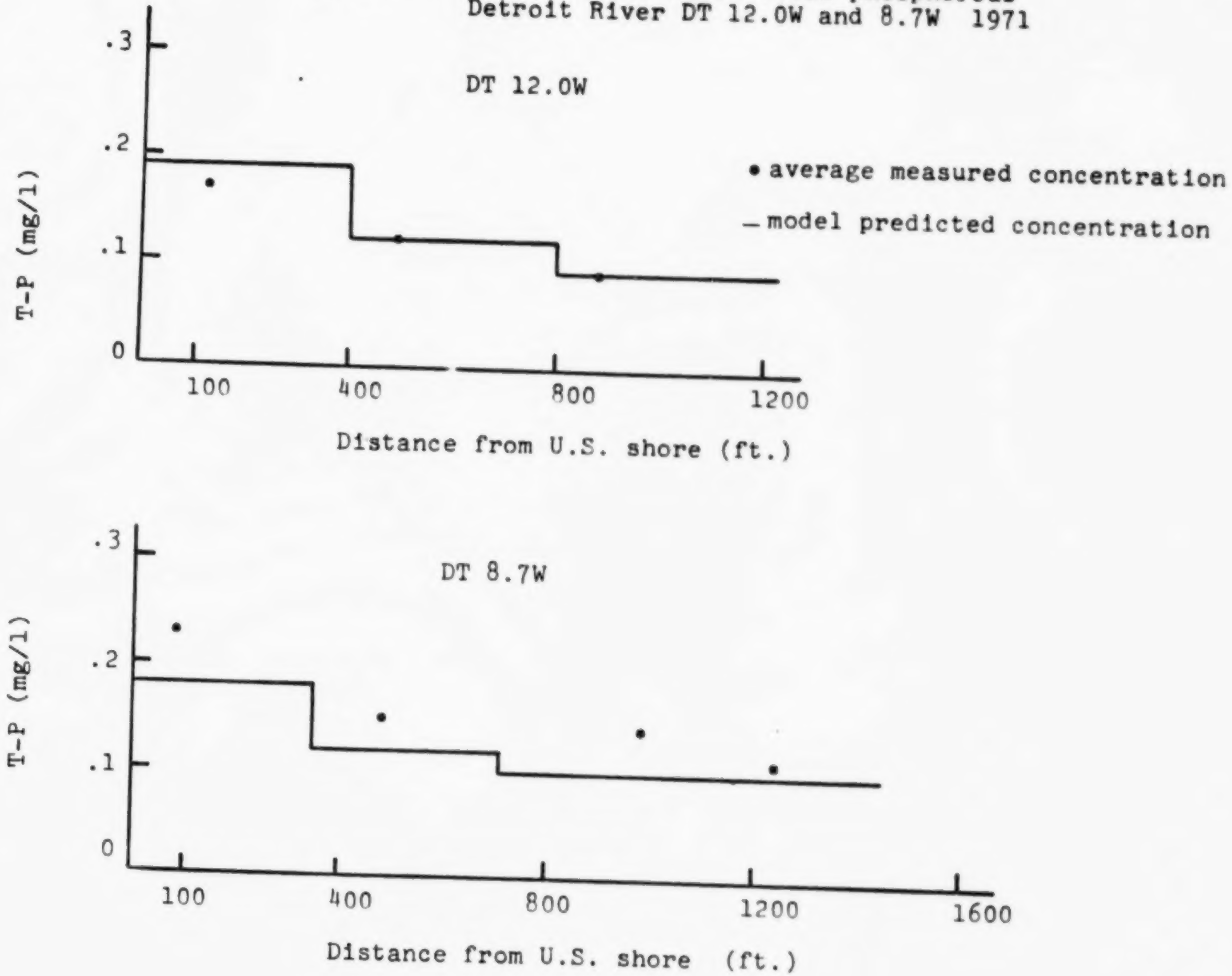
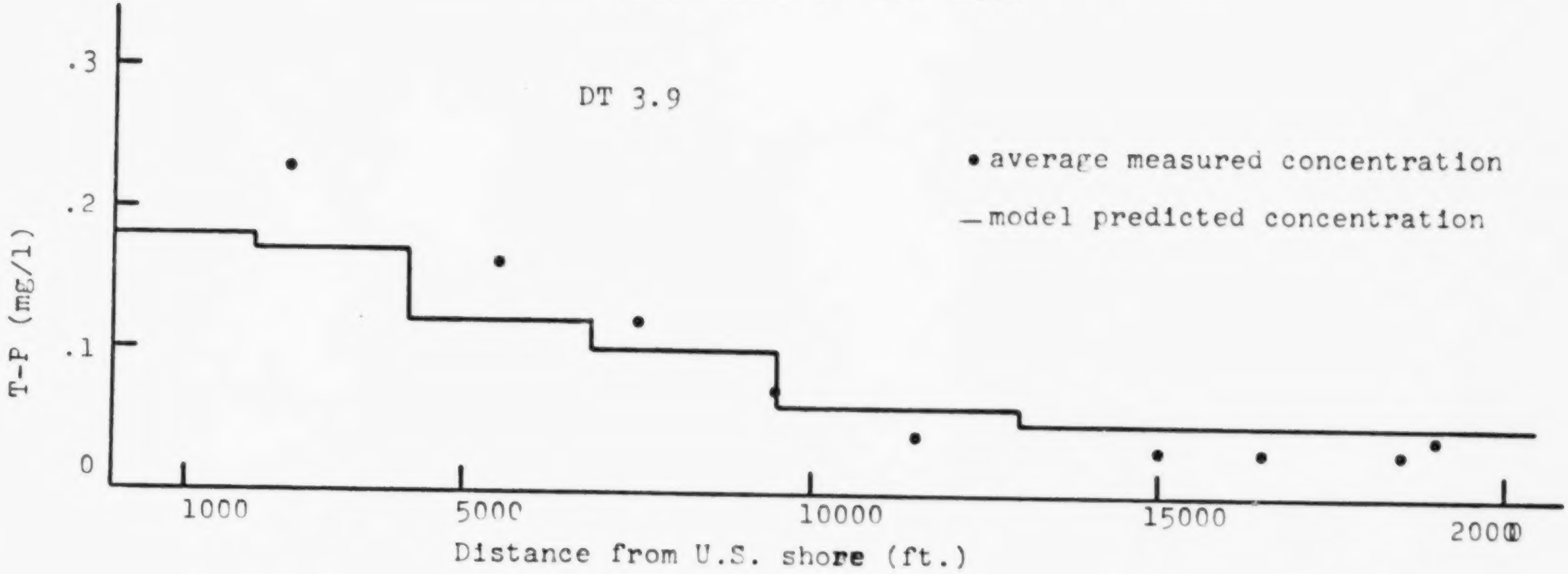


Figure 82. Model verification - Total Phosphorous
Detroit River DT 3.9 1971



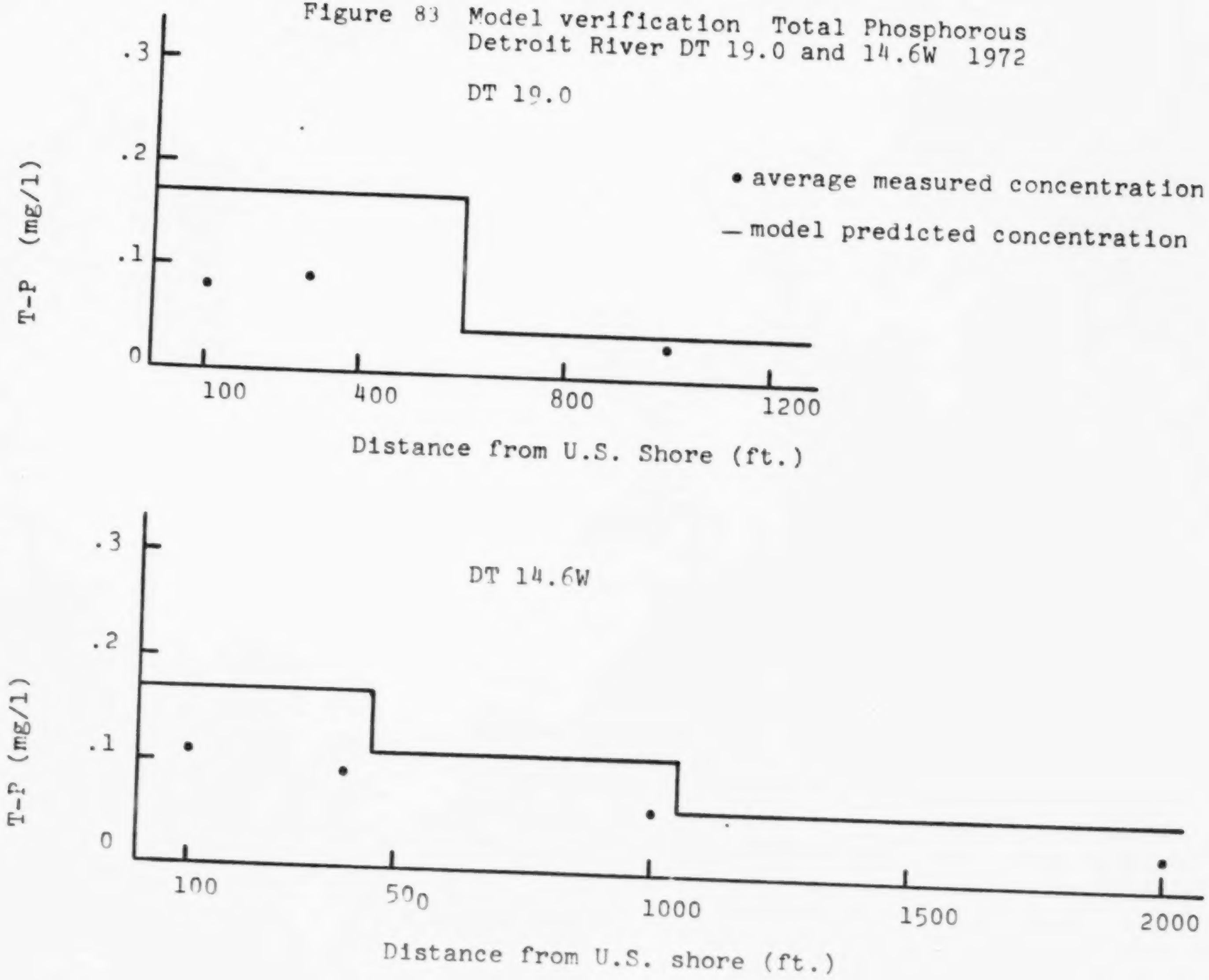


Figure 83 Model verification Total Phosphorous Detroit River DT 19.0 and 14.6W 1972

Figure 84 Model verification - Total Phosphorous Detroit River DT 19.0 and 14.6W 1973

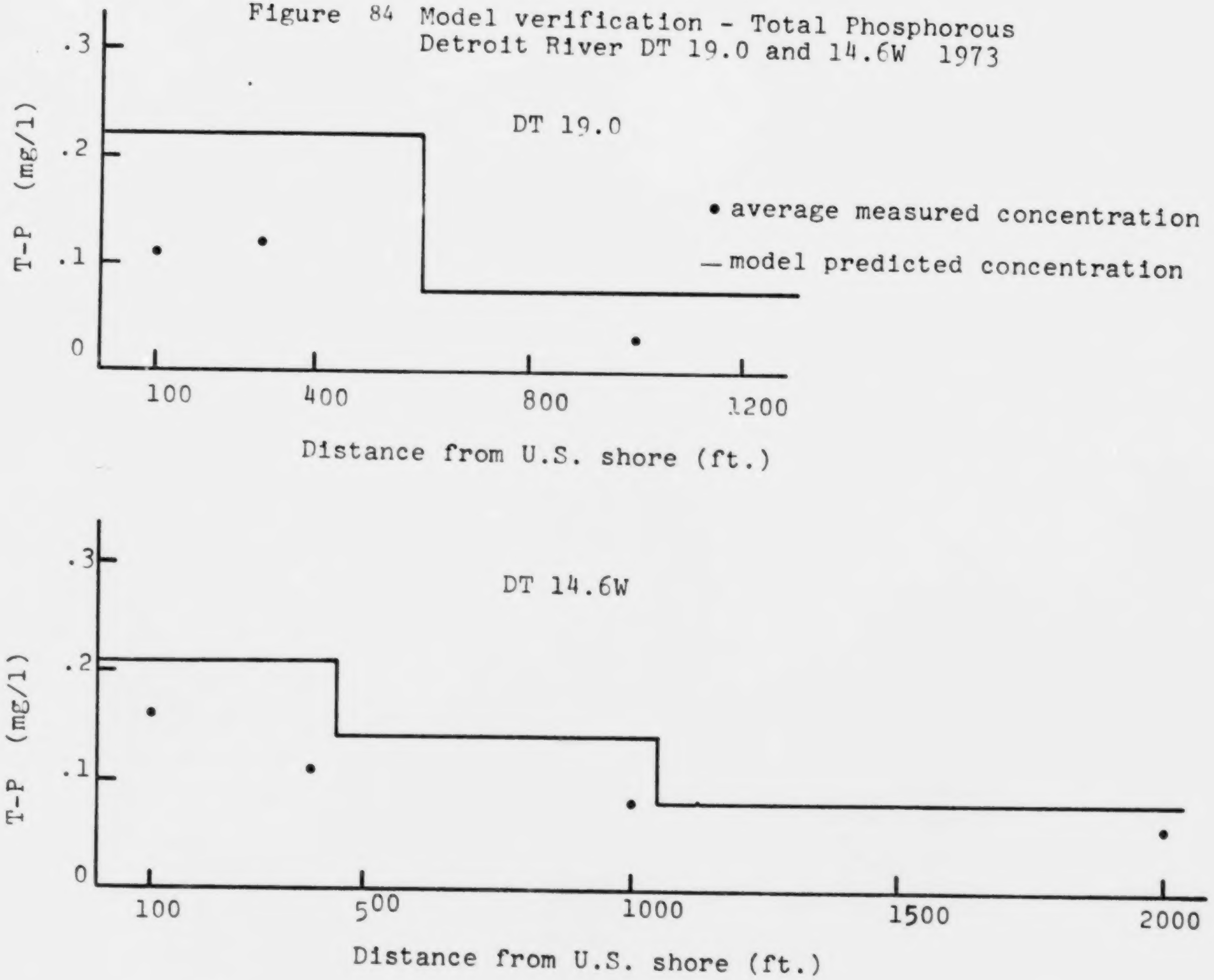


Figure 85 Model verification Total Phosphorous Detroit River DT 12.0W and 8.7W 1972

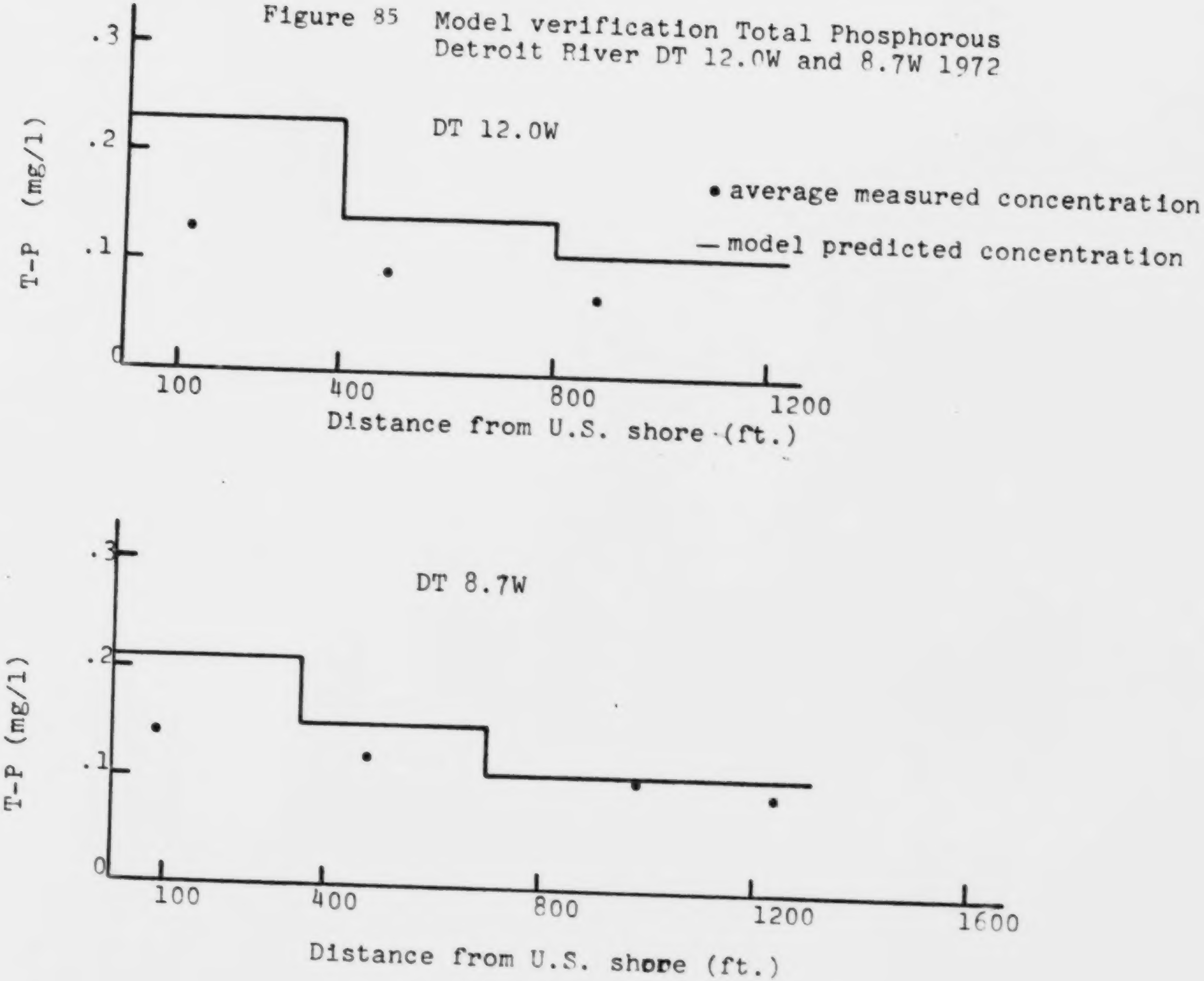


Figure 86. Model verification Total Phosphorous
Detroit River DT 12.0W and 8.7W 1973

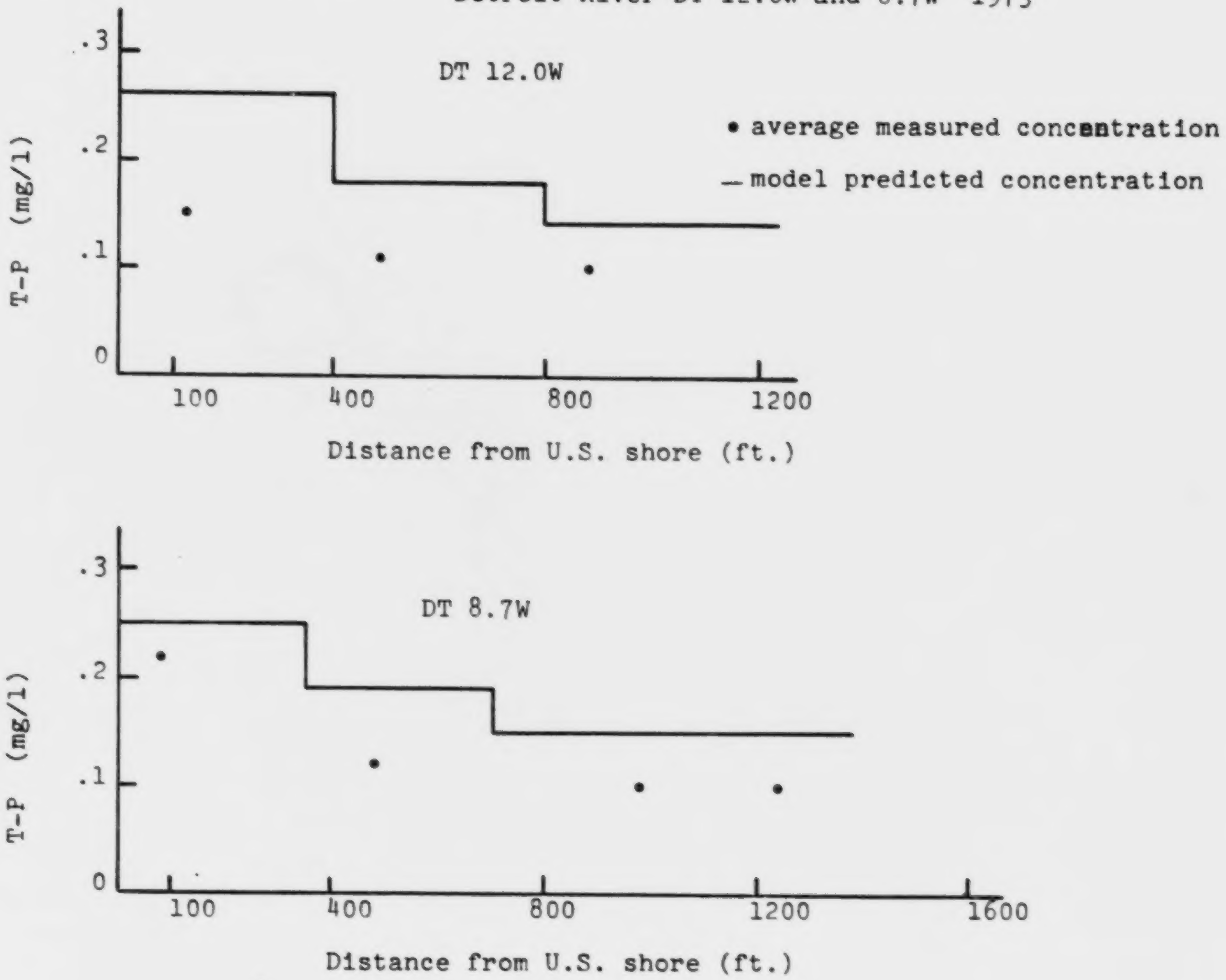


Figure 87. Model verification Total Phosphorous
Detroit River DT 3.9 1972

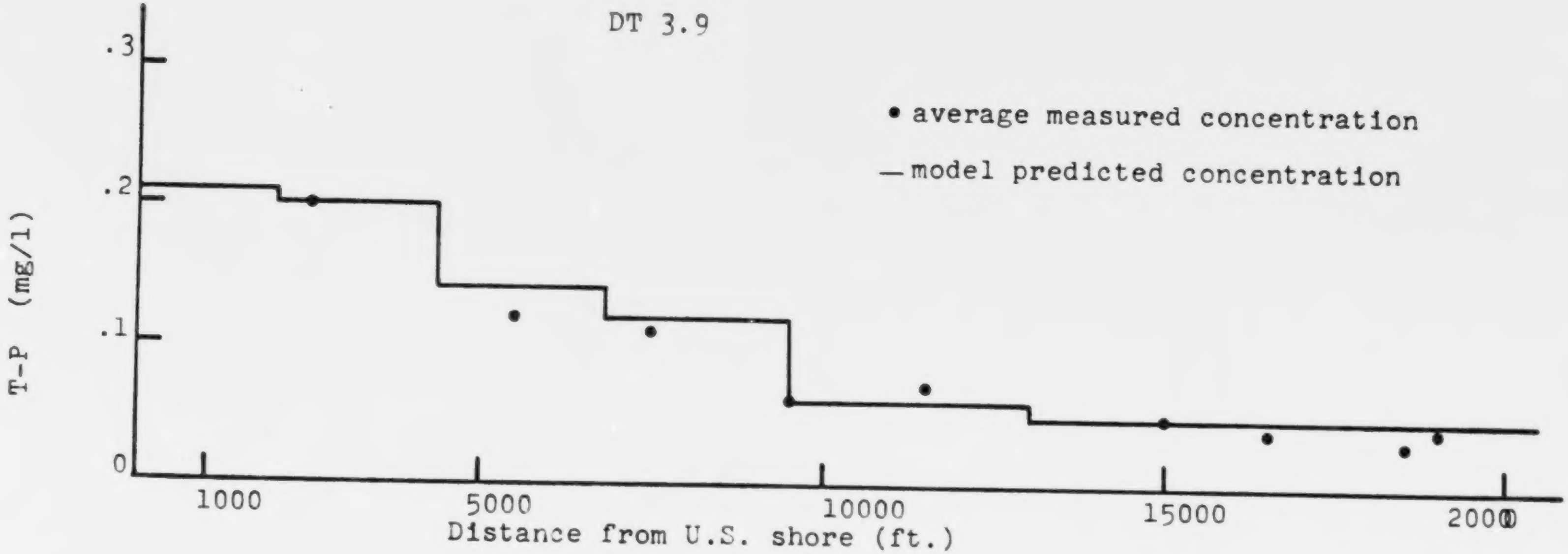
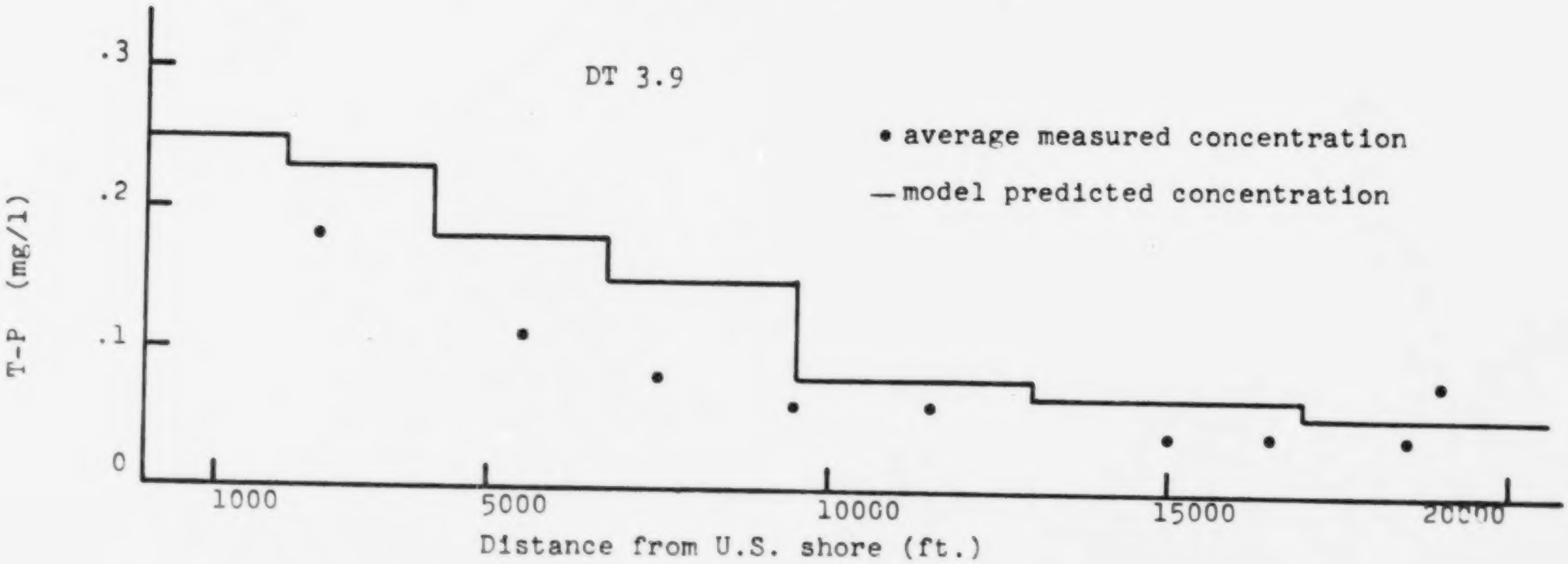


Figure 88. Model verification Total Phosphorous
Detroit River DT 3.9 1973



straightforward. Through the use of appropriate input loads, the effects of various loading levels, outfall placement, and other conditions can be estimated. Proper interpretation of model output can provide insight not only to the effects of waste discharges on river water quality, but also to other utlimate effects in the water quality of Lake Erie.

The model can also aid in pinpointing those areas of the river which are most critical in terms of water quality. The evaluation of phenol and iron conditions in the river serves as a good example. As discussed earlier, the section of river between milepoints 17.4W and 14.6W showed a decrease in both phenol and iron levels. During the modeling program it became obvious that this area deserved special attention because of this drop in concentration and the large effects on the downstream areas. The results of the model study were substantiated and supported by the biological and chemical data obtained during the surveys. Thus, this area is considered a special section of the river and should be considered in more detail during future studies on the river. The end segments of the model are designed to provide input data for Lake Erie. It is anticipated that the Detroit model can be used in conjunction with the Hydroscience Model for lake Erie to aid in evaluating alternative plans for the management of this section of the Great Lakes. Through the proper use of these models, the changes in water quality due to various control programs along the Detroit River and changes in the water quality of Lake St. Clair can be evaluated according to their impact on the Lake Erie system.

As in the case of any model, the Detroit River model should be updated and reverified as additional data becomes available. A program of continual revaluation will assure that the model reflects current river conditions and will help establish the model as a valuable asset in the management of the river system.

SECTION VII

WATER QUALITY PROJECTIONS

The water quality projections discussed in this section are based on observed historical trends in water quality, analytical results obtained during this study, and application of the developed mathematical model, using tentative effluent limitations provided by the State of Michigan. Each of these areas has been discussed in previous sections, and serves as a foundation for the projection of water quality under various control alternatives. Industrial loadings are based on permits issued by the State of Michigan under the National Pollutant Discharge Elimination System. While these permits are still under review and may be altered to some degree, they do provide an indication of future loadings that can be expected. This loading data, utilized in conjunction with the developed mathematical model, allows a quantitative projection of future levels for pollutants such as chloride, phenol, ammonia nitrogen, phosphorus and total iron. Background and loading data for other parameters such as heavy metals is not sufficient at this time to allow a quantitative projection of future levels, however, anticipated water quality conditions can be discussed on a qualitative basis. It should be understood at this time that all of the various projections made, whether qualitative or quantitative, are based on a set of assumed conditions. (Flow rates, flow pattern, incoming water quality for Lakes St. Clair and Huron, etc.) If these conditions change, the resultant water quality may vary appreciably from the projected levels.

For each of the projections in which the mathematical model was used, several assumptions were needed. The boundary conditions for the incoming water to the river were set based on 1973 measured values. The flow rate was assumed to be 175,000 cfs, which is a low flow compared to recent years. It was felt that a conservative set of conditions would be best for the projection of critical conditions. The model is based on an established flow and mixing pattern, thus it is assumed in these projections that no major changes in the flow pattern will occur.

The segmentation scheme for the model is detailed in the modeling section of this report.

For purposes of discussion, the concentrations mentioned will be the average concentration in one segment. Therefore, when a maximum average concentration is discussed and compared with a water quality standard, that concentration will represent the highest level for all segments of the river. In most cases this high level will occur in a shoreline segment near a major outfall. It should be noted that in most cases the segments in the center of the river will be much lower in concentration. Also, the entire discussion and projections using the model are for the U. S. side of the river only. The Canadian side of the river has not been included as the model was not verified for Canadian shoreline stations nor was any industrial loading data for the Canadian side available at the time of this report.

Little change in existing quality can be anticipated in the St. Clair River. Generally speaking, the St. Clair River is presently characterized by high quality water, and compliance with more stringent effluent guidelines will simply assure that this high quality continues. The primary parameter of concern with regards to meeting current international water quality guidelines for the St. Clair River is phenol. In recent years the concentration of this parameter has failed to meet the established guidelines of 2 μg/l average and 5 μg/l maximum near the Canadian shore at milepoints SR 30.7 and SR 33.1, and near the United States shore at milepoints SR 33.9, SR 34.4, and SR 35.0. Compliance by industries on both sides of the river with the effluent guidelines established in 1972 amendments is necessary in order to decrease the river concentration of this material to the desired level.

Similarly, the upstream portion of the Detroit River (above the confluence with the Rouge River) is presently of such a quality as to meet present standards. The only major sources of waste loads in this section of the river are combined sewer overflows from the City of Detroit. In the past these overflows had a large influence on the water quality. In recent years, however, the City of Detroit has implemented a control system whereby overflow occurrences have been greatly reduced, and consequently exerted less detrimental influence on water quality.

The lower section of the Detroit River (Zug Island to Lake Erie) receives the largest waste loads, and is the area where water quality standards are violated most often. At the present time, phenol standards of 2.0 μg/l average and 5 μg/l maximum are violated at shoreline stations from the Detroit Waste Treatment Plant to Lake Erie. As indicated in the trend analysis, there has been considerable improvement in the river even though standards are still violated at some stations. This improvement has been due largely to the Industrial Control Program that has been initiated. Many industries are now meeting effluent guidelines and it is anticipated that more will comply in the future.

The mathematical model was used to project anticipated future levels of five chemical constituents in the Detroit River. These parameters include chloride, phenol, ammonia nitrogen, phosphorus and total iron. The projections made with the model are for the year 1977 and are based on the industrial loadings authorized under the National Permit Program. Effluent loadings for the Detroit Wastewater Treatment Plant (Det WWTP) were based on available information where possible, although in the ammonia nitrogen, chloride, and iron simulations, values had to be assumed. For each case where an estimated concentration was used, an average flow rate of one billion gallons per day (1 BGD) was assumed.

As mentioned previously, the chloride standard of 50 mg/l is presently achieved at all points in the river. Simulation, assuming an average of 175 mg/l in the Det WWTP effluent and allowed loadings for all industries, showed a maximum average concentration of 48 mg/l. This occurred below the industrial outfalls in the Trenton Channel (Segment 37). It is important to note that the chloride loadings allowed under the permits are generally higher than the present discharge levels. Therefore, if it present industrial discharge levels are maintained the chloride standard will continue to be met.

It was stated earlier that the phenol standard was violated at many near shore areas of the Detroit River. The new phenol limitations placed on the industries and on the Det WWTP (93 lb/day) are much lower than the levels presently being discharged, and were entered into the model. As discussed in the modeling section it was necessary to insert a phenol "sink" in the model in order to verify the results. The exact nature of this sink and its interrelationship with other parameters are not completely understood. Therefore no loss of phenol to such a "sink" was assumed for projections using the model. By removing this sink, the projection may be more conservative than the actual conditions warrant. The results showed that near shore segments at milepoint 8.7W and 3.9 (the most critical reaches) would average 3.0 ppb of phenol. This would indicate a violation of the standard at those locations, however, this degree of violation is minimal, and thus it is difficult to state definitely whether the standard will be violated. Also, any effects of degradation or sorption-sedimentation of this material will serve to further decrease its concentration in the aqueous phase. The large reduction in the total pounds of phenol entering the river will definitely result in a significant improvement in the water quality with respect to phenol contamination should be realized.

Ammonia nitrogen levels should decrease as the new discharge levels are met. The exact degree of reduction will depend primarily on the removal attained by the Det WWTP. Little data on the Det WWTP ammonia levels is available, consequently three simulations were carried out. The first run was based on 1 BGD flow, and 8 mg/l NH_3 -N from the Det WWTP and all industries in compliance with the permits. Runs 2 and 3 are based on a Det WWTP discharge of 4 and 1 mg/l, respectively. The results from these simulations show that with .030 mg/l NH_3 -N entering the river from Lake St. Clair a maximum average concentration of from 0.41 to 0.21 mg/l can be expected (high level based on Det WWTP 8 mg/l, low level based on Det WWTP 1 mg/l). This represents a reduction in the ammonia nitrogen concentration of between 25 and 75 percent in the near shore areas.

The phosphorus projections were also based on various estimated effluent levels from the Detroit plant and compliance by the various industries with the permit program. The present standard for phosphorus for the Det WWTP is 4750 lbs/day, or 0.56 mg/l at one billion gallons per day flow. Simulation using this loading along with allowed industrial discharges showed a maximum average concentration expected of 0.13 mg/l, whereas presently the value is averaging 0.18 mg/l. A second run with the Detroit plant discharging at an average level of 1 mg/l, the established international goal, showed an expected maximum of 0.14 mg/l. Thus the new limitations will definitely decrease the phosphorus concentrations in the river, and in fact those areas along the shoreline can be expected to drop by approximately 20-30 percent in phosphorus concentration.

Iron values obtained during the model verification are based on total iron measurements. The standard for iron is set on filtrable iron concentration, and consequently cannot be compared directly with model output. Two effluent levels of 4 and 9 mg/l T-Fe were used as esimates for the Det WWTP. The results of the simulation indicated a substantial reduction in total iron concentration with a maximum average value of 0.57 or 0.70 mg/l depending on the assumed Detroit plant loading. This represents a substantial reduction in iron levels, and while it is not clear whether the 0.03 mg/l filtrable iron standard will be met, it is anticipated that the river will show a marked reduction in iron concentration. Graphical representation of the above projections is given in Appendix D-9.

Five-day biochemical oxygen demand (BOD_5) and total suspended solids were not modeled in this study. The BOD of the river was not large although the area near the Detroit

Wastewater Plant and Rouge River definitely showed a BOD increase. The Detroit plant has been discharging on the order of one half million pounds per day of BOD_5. The new discharge level is expected to be much lower with a standard of 200,000-250,000 lbs/day. This will definitely aid the river by lowering the oxygen demand. Similarly, the Det WWTP and the various industries are required to lower the suspended solids discharged to the river by better than 50 percent in almost all cases. This will enhance the water quality, not only by an improvement in the aqueous phase, but also by an improvement in the sediment condition, with fewer solids, along with sorbed materials, being settled to the bottom.

In summation, it is apparent that the water quality in most cases has improved in recent years. The new limitations issued for discharges indicate that this trend will continue and that water quality standards will either be met or approached very closely in the next few years. The exact fate of some of the trace metals and the role of sediment chemistry has not been defined adequately to make a complete evaluation at this time. However, it is hoped that further research in these areas will provide the necessary information to assess their importance in river management.

SECTION VIII

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APPENDIX

Table A-1: Aqueous Phase (Insitu) Data Summary - August 1973 Survey

Station	Depth (ft.)	Dissolved Oxygen (mg/l)	Temp. (°C)	Specific Conductance (μmho)
1	0	10.2	23.0	200
	6	7.7	22.5	182
	12	6.7	22.2	189
	18	6.1	22.3	202
2	0	8.8	23.0	198
	6	8.8	23.0	202
	12	8.7	22.7	201
	18	8.8	21.9	194
	30	8.8	21.9	194
3	0	9.3	21.0	203
	6	9.4	21.8	208
	12	9.0	21.1	212
	18	8.2	21.2	209
	30	6.8	20.8	207
4	0	9.2	20.8	195
	6	9.2	21.0	194
	12	8.9	20.9	198
	18	7.9	20.9	198
5	0	9.3	23.5	240
	6	9.1	22.5	238
	12	6.0	22.5	231
	18	4.8	23.0	225
	24		22.9	
	30	3.5	23.0	260
6	0	8.1	23.1	255
	6	8.7	23.1	257
	12	8.4	23.1	257
7	0	9.3	23.3	250
	6	9.0	23.0	250
	12	8.8	23.2	251
	18	7.5	23.1	257
	24	6.8	23.1	253
8	0	9.1	23.8	269
	6	8.8	24.0	269
	12	8.7	24.0	269
	18	6.6	23.9	268
	30	5.6	23.5	272
9	0	8.7	23.2	260
	6	8.3	23.2	261
	12	8.2	23.3	260
	18	8.0	23.1	261

Table A-1: Aqueous Phase (Insitu) Data Summary - August 1973 Survey (continued)

Station	Depth (ft.)	Dissolved Oxygen (mg/l)	Temp. (^{o}C)	Specific Conductance (μmho)
	30	5.0	23.1	267
10	0	7.4	24.5	307
	12	7.7	24.2	285
	18	8.3	24.0	282
	30	4.4	24.0	284
11	0	8.6	23.8	261
	12	8.8	23.9	261
	30	8.0	24.0	263
12	0	7.9	23.8	287
	6	7.4	23.8	281
	12	6.3	23.8	281
	18	5.4	23.8	278
	30	4.9	23.8	283
13	0	8.3	24.7	282
	6	8.4	24.3	282
	12	8.0	24.0	283
	18	7.2	24.1	282
	24	6.3	24.1	282
14	0	8.9	24.0	265
	6	9.2	24.0	262
	9	8.6	24.0	261
	30	7.2	23.9	263
15	0	8.2	24.4	283
	6	8.3	24.0	282
	12	8.0	24.0	282
	18	7.0	24.1	282
	30	5.2	24.1	282
16	0	8.5	24.0	270
	6	8.2	23.9	268
	12	7.8	23.9	268
	18	8.2	23.9	269
	30	7.8	23.9	272
17	0	8.2	24.0	295
	6	7.9	23.0	290
	12	7.2	22.9	285
	18	6.1	22.9	283
	30	5.6	22.8	288
18	0	8.6	25.0	287
	6	7.6	24.8	310
	12	7.4	26.0	313
	18		24.3	312
	22		24.0	301

Table A-1: Aqueous Phase (Insitu) Data Summary - August 1973 Survey (continued)

Station	Depth (ft.)	Dissolved Oxygen (mg/1)	Temp. (°C)	Specific Conductance (μmho)
19	0	6.7	26.0	342
	6	6.3	26.0	339
	10	5.9	26.0	339
20	0	8.9	25.0	308
	6	8.1	24.9	309
	12	7.6	24.9	311
21	0	8.9	24.9	299
	6	8.6	24.8	298
	12	8.1	24.8	297
22	0	8.4	24.0	298
	6	8.1	24.0	293
	12	7.0	23.9	292
	18	4.9	24.0	291
	30	3.4	24.0	292
	34	3.8	24.0	287

Table A-2: Aqueous Phase (Insitu) Data Summary - November 1973 Survey

Station	Depth (ft.)	Dissolved Oxygen (mg/1)	Temp. (°C)	Specific Conductance (μmho)
1	6	3.0	10.0	142
	24	0.6	10.0	150
2	0	11.7	10.0	191
	12	9.4	10.0	189
	24	5.2	10.0	189
3	0	11.5	10.0	200
	12	8.3	10.0	192
	24	8.8	10.0	192
4	0	11.8	10.0	198
	12	8.4	10.0	198
	30	5.3	10.0	190
5	0	12.8	6.0	170
	12	7.2	7.0	172
	24	5.2	7.5	169
6	0	12.6	8.0	170
	12	6.4	8.0	173
	24	5.2	8.0	169
7	0	12.6	6.5	185
	12	11.6	6.5	185
	24	7.5	6.5	180
8	0	12.6	7.5	170
	12	12.4	7.5	170
	24	11.5	7.5	170
9	0	12.4	7.6	170
	12	12.4	7.6	170
	30	6.9	7.8	169
10	0	11.3	8.0	188
	12	11.3	8.0	170
	30	9.0	8.0	165
11	0	12.2	7.5	160
	12	12.1	7.5	160
	30	11.7	7.5	160
12	0	12.8	6.5	205
	12	12.8	6.5	220
13	0	12.0	7.0	192
	12	11.8	8.0	190
	24	11.8	8.0	192
14	0	12.8	7.0	178
	3	12.4	7.0	178

Table A-2: Aqueous Phase (Insitu) Data Summary - November 1973 Survey (continued)

Station	Depth (ft.)	Dissolved Oxygen (mg/l)	Temp. (°C)	Specific Conductance (μmho)
15	0	11.5	8.0	185
	12	11.5	8.0	182
	30	12.0	8.0	175
16	0	13.2	7.0	215
	12	13.0	7.0	218
	24	13.2	7.0	218
17	0	13.4	6.5	278
	6	13.4	6.5	270
18	0	11.0	8.0	205
	12	11.4	8.0	200
	18	11.3	8.5	210
19	0	11.6	8.0	170
	6	11.6	8.0	172
20	0	12.0	8.0	161
	12	-	-	-
21	No data obtained: Equipment malfunction			
22	0	12.8	7.0	460
	12	12.8	7.0	380

Table A-3: Aqueous Phase (Insitu) Data Summary - May 1974 Survey

Station	Depth (ft.)	Dissolved Oxygen (mg/l)	Temp. (°C)	Specific Conductance (μmho)
1	0	12.6	7.0	133
	10	12.4	6.9	133
	20	12.4	6.9	133
	30	12.2	6.8	135
2	0	12.8	6.0	131
	10	12.6	6.3	132
	20	12.6	6.3	131
	30	12.6	7.5	132
3	0	13.0	7.8	167
	10	12.7	7.0	158
	20	12.6	7.0	167
	30	12.6	7.0	160
4	0	12.4	8.0	155
	10	12.2	8.0	155
	20	12.2	7.9	153
	30	12.4	7.8	153
5	0	11.8	9.0	200
	10	11.8	8.9	200
	20	11.7	8.8	205
6	0	11.7	7.8	208
	10	11.6	7.7	208
	20	11.6	7.6	206
	30	11.5	7.4	206
7	0	11.6	7.9	231
	10	11.4	7.7	230
	20	11.3	7.5	230
	30	11.2	7.4	230
8	0	11.6	9.0	220
	10	11.4	8.8	220
	20	11.4	8.5	218
	30	11.3	8.5	215
9	0	12.0	8.0	190
	10	11.6	8.0	190
	20	11.4	7.9	188
	30	11.4	7.9	190
10	0	9.8	10.9	270
	10	9.5	9.8	220
	20	9.6	9.0	240
	30	10.8	9.0	215
11	0	11.2	8.5	185
	10	11.3	8.3	188
	20	11.4	8.1	188
	30	11.3	8.1	186

Table A-3: Aqueous Phase (Insitu) Data Summary - May 1974 Survey (continued)

Station	Depth (ft.)	Dissolved Oxygen (mg/l)	Temp. (°C)	Specific Conductance (µmho)
12	0	8.8	11.8	-
13	0	10.4	10.0	-
	10	10.6	10.0	-
	20	10.8	10.5	-
	30	11.1	10.6	-
14	0	11.4	11.0	-
15	0	10.4	11.3	201
	10	10.4	11.1	200
	20	10.4	11.2	199
	30	10.6	11.0	193
16	0	11.2	9.9	233
	10	11.0	9.2	237
	20	11.0	9.2	238
	30	11.0	9.0	240
17	0	11.0	10.1	277
18	0	10.5	11.9	233
	10	10.3	11.7	230
	20	10.4	11.3	228
19	0	10.2	13.0	235
	10	10.2	12.5	223
20	0	10.9	11.0	173
	10	11.0	11.0	174
21	0	11.2	10.5	170
	10	11.2	10.3	170
	20	11.2	10.3	170
22	0	11.3	10.5	199
	10	11.2	10.4	195

Table A-4: Aqueous phase data summary - August 1973 survey

Parameter	Units	Stations																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Date taken	-	14	14	14	14	15	15	15	15	15	15	15	16	15	15	15	16	16	15	15	.5	15	15
BOD	mg/l	0.9	0.9	0.3	1.9	2.4	1.2	0.8	1.8	1.1	4.6	1.1	1.5	3.9	1.7	3.9	1.5	0.7	4.2	2.6	1.9	2.6	0.6
COD	mg/l	10.2	12.9	9.9	9.2	8.0	9.7	8.7	10.7	8.2	17.9	12.9	8.7	12.9	12.2	10.4	12.7	10.2	12.4	14.2	8.2	8.0	8.0
Cd	μg/l	0.47	0.45	0.35	0.62	0.49	0.35	0.35	0.29	0.28	0.64	0.25	0.33	0.68	0.30	0.55	0.34	0.35	0.90	0.75	0.53	0.43	0.33
Cr	μg/l	4.9	9.9	14.2	10.1	9.8	11.8	16.8	5.5	27.8	15.1	7.9	13.0	21.6	8.3	8.3	18.7	19.5	16.3	21.3	20.0	6.2	21.3
Cu	μg/l	6.3	4.7	3.4	7.9	3.9	11.2	3.1	4.0	3.4	13.3	2.3	5.4	18.8	3.1	7.1	5.2	4.0	12.3	10.7	6.8	6.0	2.8
Fe	μg/l	50	70	120	120	960	420	2490	550	490	2600	490	2170	4750	1420	2020	1150	1250	2690	4850	1420	1570	1040
Hg	μg/l	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
Mn	μg/l	1.7	2.1	4.5	4.0	19.0	11.7	21.8	14.4	12.4	30.5	11.8	26.9	52.6	12.9	26.2	15.3	14.6	27.0	43.6	17.9	16.9	12.5
Ni	μg/l	11	11	15	15	23	19	15	27	15	23	11	11	23	11	23	19	15	19	47	23	19	15
Pb	μg/l	1.7	2.1	2.0	2.3	2.3	1.6	2.1	1.9	1.7	4.2	1.7	1.8	5.3	1.4	3.2	2.2	1.9	5.4	6.4	3.5	3.0	2.2
Zn	μg/l	221	66	48	90	66	72	96	48	54	72	36	54	96	42	60	60	66	84	78	60	84	48
Chlorinated hydrocarbons	μg/l	0.66	0.51	0.46	0.50	0.30	0.44	0.25	0.32	0.48	0.50	0.58	0.37	0.36	0.54	0.22	0.46	0.38	0.73	0.43	0.53	0.67	0.58

Table A-5: Aqueous phase data summary - November 1973 survey

Parameter	Units	Stations																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Date taken	-	6	6	6	6	7	7	7	7	7	7	7	8	8	8	7	8	8	7	7	7	8	9
BOD	mg/l	1.0	1.0	1.6	1.2	1.2	1.2	1.4	1.4	1.2	3.3	1.0	1.9	3.3	1.9	2.7	1.4	2.0	3.8	2.8	1.2	1.6	1.8
COD	mg/l	3.0	4.2	6.0	6.5	6.7	7.5	5.7	4.2	6.2	7.5	4.2	13.4	10.5	6.2	10.0	6.7	10.5	12.2	11.9	6.5	11.9	9.0
Cd	μg/l	0.24	0.15	0.19	0.13	0.26	0.37	0.41	0.54	0.27	0.68	0.43	0.31	0.66	0.24	0.81	0.14	0.23	1.58	1.46	0.26	0.23	0.46
Cr	μg/l	2.6	5.8	3.4	3.4	3.8	5.1	6.2	6.4	7.4	13.5	6.6	8.4	18.6	7.1	9.7	3.6	10.3	17.1	13.7	5.8	5.0	7.4
Cu	μg/l	7.0	5.4	8.5	7.2	6.6	4.8	10.5	20.4	10.9	13.3	8.8	9.0	9.0	5.3	9.1	3.5	5.0	13.7	12.7	6.4	4.3	8.9
Fe	μg/l	160	120	300	230	460	490	1000	650	800	1340	720	1320	1120	650	1170	670	1710	1670	980	560	570	1260
Hg	μg/l	6.1	9.0	2.4	4.8	4.2	8.3	7.3	6.6	1.1	7.0	7.7	12.0	6.5	2.8	1.6	5.5	6.4	4.1	5.1	5.3	4.6	5.8
Mn	μg/l	3.7	2.8	6.5	5.9	7.8	9.7	14.2	6.8	13.8	22.0	9.0	21.9	18.9	9.7	18.3	9.2	27.5	22.2	18.1	8.6	10.7	20.1
Ni	μg/l	11	23	19	15	11	11	15	15	15	23	15	23	27	15	19	11	15	19	23	15	11	15
Pb	μg/l	4.2	3.7	3.1	3.2	2.7	3.5	4.6	10.9	5.8	7.2	4.5	4.7	7.7	3.6	6.0	3.2	3.4	10.8	6.5	3.6	3.3	6.4
Zn	μg/l	56	35	56	63	63	49	84	155	91	84	70	56	42	42	70	56	70	141	84	70	56	84

Table A-6: Aqueous phase data summary - May 1974 survey

Parameter	Units	Stations																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Date taken	-	13	13	13	13	14	14	14	14	14	14	14	15	15	15	14	14	14	14	14	14	14	14
BOD	mg/l	1.6	1.3	2.1	1.6	1.8	1.8	1.7	2.1	2.2	3.4	1.5	2.5	1.8	2.6	2.9	1.3	1.6	3.2	3.8	1.6	1.6	1.8
COD	mg/l	3.9	5.1	6.7	5.2	5.3	5.4	4.8	6.7	3.5	13.0	6.2	9.8	8.9	7.1	11.8	3.2	7.6	14.2	13.1	7.9	7.0	6.3
Cd	µg/l	0.42	0.15	0.13	0.15	0.12	0.28	0.23	0.17	0.18	0.34	0.12	0.19	0.37	0.20	0.35	0.16	0.24	0.53	0.65	0.15	0.67	0.57
Cr	µg/l	0.6	0.5	0.6	1.1	0.9	10.5	1.0	1.0	1.2	8.6	1.3	7.2	9.9	4.6	14.3	1.6	1.7	13.0	16.3	4.4	1.8	1.7
Cu	µg/l	4.6	4.2	3.2	6.4	3.4	5.4	5.5	6.4	8.5	10.3	6.3	6.0	17.3	40.6	8.6	6.5	8.2	13.4	12.5	6.5	7.0	18.0
Fe	µg/l	70	30	200	250	330	350	490	330	330	1410	470	730	940	540	820	500	690	1490	1060	860	350	350
Hg	µg/l	0.4	0.1	0.1	<0.1	4.6	0.3	0.6	0.2	0.1	<0.1	0.1	0.8	0.7	0.1	0.1	0.8	0.1	0.3	0.1	0.1	0.1	0.3
Mn	µg/l	3	3	8	5	10	10	15	10	10	6	15	44	37	21	28	13	17	41	33	25	10	10
Ni	µg/l	7	27	19	11	15	11	11	11	19	27	31	47	27	27	27	15	23	31	23	15	19	15
Pb	µg/l	0.7	1.0	0.6	0.7	0.9	1.0	1.3	1.3	1.3	7.1	1.3	6.4	15.8	7.3	11.9	4.1	4.1	13.7	14.7	5.8	4.0	6.4
Zn	µg/l	57	51	53	93	59	77	86	64	77	84	69	142	130	110	101	107	94	86	90	66	72	95

Table A-7: Aqueous phase (pesticides) data summary - November and May surveys

Parameter	Units	Stations																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
November 1973 survey																							
Lindane	ng/l	-	<2	2.7	<2	3.8	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Heptachlor	ng/l	-	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8	<8
Aldrin	ng/l	-	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7	<7
Heptachlor Epoxide	ng/l	-	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
P, p' DDE	ng/l	-	<14	<14	<14	<14	<14	<14	<14	<14	<14	<14	<14	<14	<14	<14	<14	<14	<14	<14	<14	<14	<14
Dieldrin	ng/l	-	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20	<20
P, p' TDE (DDD)	ng/l	-	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30	<30
Endrin	ng/l	-	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40	<40
P, p' DDT	ng/l	-	<30	<30	60	60	30	<30	<30	<30	<30	<30	<30	<30	<30	<30	30	51	45	<30	30	<30	<30
May 1974 survey																							
Lindane	ng/l	<1	3.8	5.3	5.3	3.8	2.7	<1	1.1	<1	3.8	2.7	2.7	1.1	<1	<1	<1	<1	7.6	7.6	3.8	2.7	2.7
Heptachlor	ng/l	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Aldrin	ng/l	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2	<2
Heptachlor Epoxide	ng/l	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3	<3
P, p' DDE	ng/l	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4	<4
Dieldrin	ng/l	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6	<6
P, p' TDE (DDD)	ng/l	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
Endrin	ng/l	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10	<10
P, p' DDT	ng/l	<10	10	<10	10	<10	<10	<10	<10	<10	15	<10	30	<10	<10	<10	<10	<10	10	10	10	21	30

Table A-8: Sediment phase data summary - August 1973 survey

Parameter	Units	Stations																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Date taken	-	14	14	14	14	15	15	15	15	15	15	15	16	15	15	15	16	16	15	15	15	15	15
COD	mg/g	NS	3	25	40	13	NS	9	52	NS	157	NS	11	209	28	NS	31	27	NS	197	20	48	NS
TVS	% Dry Wt.	NS	6.0	9.7	10.7	9.6	NS	3.6	7.4	NS	12.2	NS	2.4	21.0	4.7	NS	4.3	9.0	NS	15.7	6.8	9.1	NS
Kjeldahl-n	mg/kg	NS	170	290	820	310	NS	450	620	NS	1400	NS	270	5010	650	NS	610	450	NS	1340	380	750	NS
NO_3-N	mg/kg	NS	72	124	152	91	NS	86	79	NS	34	NS	99	274	74	NS	67	87	NS	331	323	135	NS
Total-P	mg/kg	NS	370	590	1010	850	NS	600	860	NS	2090	NS	500	7010	810	NS	610	890	NS	10000	3420	1090	NS
Cd	mg/kg	NS	0.5	1.4	1.7	1.5	NS	0.7	1.5	NS	11.9	NS	0.9	16.2	0.7	NS	2.3	1.2	NS	10.0	3.4	3.2	NS
Cr	mg/kg	NS	20	50	124	87	NS	47	55	NS	473	NS	33	2680	42	NS	61	41	NS	795	328	186	NS
Cu	mg/kg	NS	11	13	12	10	NS	4	45	NS	161	NS	9	199	5	NS	14	12	NS	88	35	19	NS
Fe	mg/g	NS	4.3	7.1	17.4	13.1	NS	8.2	8.2	NS	36.9	NS	5.5	38.6	7.8	NS	11.2	6.7	NS	31.6	10.2	13.6	NS
Hg	mg/kg	NS	-	-	-	-	NS	-	-	NS	-	NS	-	-	-	NS	-	-	NS	-	-	-	NS
Mn	mg/kg	NS	190	280	650	420	NS	260	330	NS	1090	NS	210	730	210	NS	480	300	NS	720	260	490	NS
Ni	mg/kg	NS	10	25	41	32	NS	17	20	NS	47	NS	13	289	14	NS	26	15	NS	87	39	31	NS
Pb	mg/kg	NS	6	266	24	15	NS	13	108	NS	242	NS	29	384	14	NS	17	25	NS	160	52	41	NS
Zn	mg/kg	NS	33	61	95	81	NS	39	86	NS	424	NS	88	444	40	NS	56	63	NS	404	266	149	NS

NS = No sample

Table A-9: Sediment phase data summary - November 1973 survey

Parameter	Units	Stations 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Date taken	-	6	6	6	6	7	7	7	7	7	7	7	8	8	6	7	8	8	7	7	7	8	8
COD	mg/g	18	NS	47	48	NS	19	NS	NS	NS	109	NS	35	110	31	37	NS	32	NS	148	109	NS	NS
TVS	% Dry Wt.	4.1	NS	6.3	5.0	NS	5.1	NS	NS	NS	6.7	NS	7.7	5.5	5.8	7.0	NS	8.4	NS	11.9	11.4	NS	NS
Kjeldahl-N	mg/kg	420	NS	820	360	NS	310	NS	NS	NS	960	NS	650	1000	590	570	NS	870	NS	1450	1770	NS	NS
NO_3-N	mg/kg	162	NS	93	172	NS	93	NS	NS	NS	94	NS	95	632	77	78	NS	207	NS	553	267	NS	NS
Total-P	mg/kg	620	NS	760	910	NS	540	NS	NS	NS	790	NS	780	2910	520	930	NS	1160	NS	3730	1440	NS	NS
Cd	mg/kg	2.9	NS	2.4	2.4	NS	2.1	NS	NS	NS	3.5	NS	2.9	5.3	2.1	2.7	NS	2.7	NS	8.2	7.5	NS	NS
Cr	mg/kg	30	NS	47	35	NS	[illegible]	NS	NS	NS	47	NS	40	166	33	40	NS	55	NS	217	180	NS	NS
Cu	mg/kg	16	NS	11	14	NS	14	NS	NS	NS	21	NS	13	103	14	15	NS	12	NS	92	55	NS	NS
Fe	mg/g	12.3	NS	21.0	20.8	NS	12.5	NS	NS	NS	15.2	NS	15.2	21.2	7.1	15.0	NS	22.8	NS	21.4	20.7	NS	NS
Hg	mg/kg	0.18	NS	0.12	0.53	NS	0.50	NS	NS	NS	4.12	NS	8.00	0.43	0.17	0.18	NS	0.86	NS	2.32	0.97	NS	NS
Mn	mg/kg	380	NS	490	510	NS	280	NS	NS	NS	580	NS	550	510	120	560	NS	960	NS	540	480	NS	NS
Ni	mg/kg	32	NS	41	46	NS	31	NS	NS	NS	43	NS	36	95	20	38	NS	45	NS	73	57	NS	NS
Pb	mg/kg	29	NS	25	30	NS	30	NS	NS	NS	58	NS	29	144	29	29	NS	30	NS	125	101	NS	NS
Zn	mg/kg	59	NS	92	87	NS	70	NS	NS	NS	131	NS	69	335	67	70	NS	90	NS	350	266	NS	NS

NS = No sample

Table A-10: Sediment phase data summary - May 1974 survey

Parameter	Units	Stations																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
Date taken	-	13	13	13	13	14	14	14	14	14	14	14	15	15	15	14	14	14	1	14	14	14	14
COD	mg/g	NS	NS	46	NS	NS	NS	14	NS	5	120	NS	88	51	73	36	85	86	NS	86	76	40	NS
TVS	% Dry Wt.	NS	NS	9.0	NS	NS	NS	3.0	NS	3.6	14.1	NS	6.8	8.0	5.1	9.7	8.1	12.1	NS	5.6	10.7	3.4	NS
Kjeldahl-N	mg/kg	NS	NS	910	NS	NS	NS	420	NS	360	1060	NS	1740	660	670	530	1470	2280	NS	980	1580	630	NS
NO_3-N	mg/kg	NS	NS	65	NS	NS	NS	45	NS	126	365	NS	67	171	73	49	89	41	NS	78	93	63	NS
Total-P	mg/kg	NS	NS	660	NS	NS	NS	660	NS	690	1590	NS	1020	1100	660	930	700	670	NS	1740	1350	430	NS
Cd	mg/kg	NS	NS	3.1	NS	NS	NS	2.6	NS	3.1	3.3	NS	3.1	4.1	2.6	3.3	2.8	2.3	NS	4.6	8.5	2.1	NS
Cr	mg/kg	NS	NS	20	NS	NS	NS	16	NS	14	32	NS	39	36	22	26	15	13	NS	48	56	9	NS
Cu	mg/kg	NS	NS	17	NS	NS	NS	14	NS	14	78	NS	20	47	30	19	19	9	NS	69	32	12	NS
Fe	mg/g	NS	NS	22.5	NS	NS	NS	17.7	NS	17.4	29.1	NS	11.6	18.2	8.6	15.1	13.3	14.7	NS	13.2	20.2	6.8	NS
Hg	mg/kg	NS	NS	<.01	NS	NS	NS	0.19	NS	0.20	0.39	NS	0.31	0.78	0.20	0.03	0.40	<.01	NS	0.58	0.42	0.17	NS
Mn	mg/kg	NS	NS	520	NS	NS	NS	480	NS	500	1120	NS	340	480	230	550	390	300	NS	330	480	230	NS
Ni	mg/kg	NS	NS	44	NS	NS	NS	30	NS	29	37	NS	59	43	22	41	30	29	NS	37	44	15	NS
Pb	mg/kg	NS	NS	21	NS	NS	NS	21	NS	16	152	NS	54	339	38	29	42	17	NS	84	80	29	NS
Zn	mg/kg	NS	NS	105	NS	NS	NS	49	NS	47	601	NS	214	225	124	124	101	49	NS	284	278	84	NS

NS = No sample

Table A-11: Sediment Description -
August, November and May Surveys

Survey	Sample	Sampling Device	Color	Description
August 1973	2	Ponar	Vary	Coarse sand & gravel
	3	Ponar	Vary	Coarse sand & gravel w/some gray ooze
	4	Ponar	Gray	Ooze w/pea size stones
	5	Corer	Gray	Ooze w/pea size stones
	7	Ponar	Vary	Sand & coarse gravel
	8	Corer	Gray	Fine gravel
	10	Corer	Gray-Black	Ooze
	12	Ponar	Vary	Sand & gravel
	13	Corer	Gray-Black	Ooze
	14	Corer	Gray	Very fine sand & gravel w/some plant materal
	16	Ponar	Gray	Ooze w/pea size stones
	17	Ponar	Vary	Sand w/gray ooze
	19	Ponar	Black	Sand w/black ooze
	20	Ponar	Black	Sand w/black ooze
	21	Ponar	Gray-Black	Sand w/ooze
November 1973	1	Corer	Vary	Sand w/coarse gravel
	3	Corer	Vary	Coarse gravel w/gray ooze
	4	Corer	Vary	Fine gray ooze w/sand & gravel
	6	Corer	Vary	Coarse gravel w/gray ooze
	10	Corer	Gray-Black	Ooze overlain w/black cinder & gravel
	12	Corer	Gray	Fine sand w/ooze & small stones
	13	Ponar	Black	Ooze
	14	Corer	Gray-Black	Sand w/small stones, organic material & plant material
	15	Corer	Gray	Ooze w/sand & small stones
	17	Corer	Gray	Ooze w/surface layer of living macrophytes
	19	Corer	Gray-Black	Ooze w/some fine sand
	20	Corer	Gray-Brown	Ooze

Table A-11: Sediment Description - August, November and May Surveys (continued)

Survey	Sample	Sampling Device	Color	Description
May 1974	3	Corer	Gray	Ooze w/gravel
	7	Corer	Vary	Gray ooze overlain by 2 cm of sand & gravel
	9	Corer	Vary	Gray ooze w/sand & gravel
	10	Corer	Black	Sand & black ooze
	12	Corer	Brown-Black	Ooze w/some detrital material
	13	Corer	Black	Ooze
	14	Corer	Brown	Sand & ooze w/some detrital material
	15	Corer	Gray-Brown	Sand & gravel w/gray ooze
	16	Corer	Gray-Brown	Sand & ooze
	17	Corer	Brown-Black	Ooze w/some detrital material
	19	Corer	Brown-Black	Ooze w/some sand
	20	Corer	Brown-Gray	Ooze w/some stones and shells
	21	Corer	Brown	Sand w/some gray ooze

Table A-12: Sediment exchange data summary - August 1973 survey

Parameter	Units	Stations 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
COD	%	NS	6.40	0.83	0.57	0.30	NS	0.86	0.68	NS	1.18	NS	2.35	0.93	2.52	NS	0.40	4.15	NS	0.85	5.90	1.96	NS
Kjeldahl-N	%	NS	4.2	2.7	3.2	2.6	NS	4.9	0.8	NS	3.8	NS	9.4	14.8	21.9	NS	1.6	16.8	NS	3.4	17.8	4.1	NS
NO_3-N	%	NS	12.2	3.4	11.8	8.4	NS	3.3	4.9	NS	23.8	NS	6.0	9.3	100.0	NS	11.2	79.1	NS	2.7	9.0	6.4	NS
Total-P	%	NS	2.2	0.2	7.8	2.0	NS	0.4	0.6	NS	0.5	NS	2.6	0.6	9.8	NS	2.5	12.7	NS	0.2	1.7	1.7	NS
Cd	%	NS	2.6	0,7	0,8	0,5	NS	2,2	3,7	NS	0,3	NS	1,8	0,4	2,9	NS	1,3	3,5	NS	0.4	6.1	0.7	NS
Cr	%	NS	6.8	0.3	1.7	0.7	NS	0,5	1.0	NS	0.3	NS	1,3	0,1	16,1	NS	1,0	8,4	NS	0,3	2.9	0,8	NS
Cu	%	NS	6.3	2.7	5.1	3.9	NS	7,2	2,5	NS	0.8	NS	7,4	1,4	55.2	NS	3,0	33.4	NS	1.4	19.7	3.2	NS
Fe	%	NS	3.7	1.1	4.8	2.2	NS	<1,0	2.9	NS	0,6	NS	4,7	2.2	8.6	NS	2.2	68.1	NS	0.8	12.8	3.5	NS
Mn	%	NS	5.8	6.1	2,9	1.6	NS	<2,1	<2,5	NS	0,8	NS	4.1	4,7	63,3	NS	1,8	38.1	NS	1.2	6,9	3.9	NS
Ni	%	NS	-	<48	<49	<44	NS	<65	<85	NS	<36	NS	-	23.2	-	NS	<69	-	NS	< 21	<49	<42	NS
Pb	%	NS	2.5	0.04	1.2	1.6	NS	0,8	0.2	NS	0,08	NS	0,5	0.05	3,5	NS	0.8	3,0	NS	0.1	1.7	0.4	NS
Zn	%	NS	-	41	45	85	NS	97	52	NS	10	NS	78	23	-	NS	-	-	NS	14	60	22	NS

NS = No Sample

Percentages are based on total concentration in dry sediment

Table A-13; Sediment exchange data summary - November 1973 survey

Parameter	Units	Stations																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
COD	%	0.69	NS	1.06	0.03	NS	2.49	NS	NS	NS	0.09	NS	0.66	0.48	2.05	0.78	NS	1.88	NS	0.60	0.51	NS	NS
Kjeldahl-N	%	3.8	NS	1.3	1.7	NS	3.6	NS	NS	NS	5.5	NS	1.8	3.8	3.1	3.5	NS	2.5	NS	2.6	3.4	NS	NS
NO_3-N	%	0.86	NS	0.22	0.58	NS	0.12	NS	NS	NS	1.49	NS	0.21	27.2	2.08	2.18	NS	0.28	NS	0.25	0.64	NS	NS
Total-P	%	2.8	NS	2.0	1.8	NS	1.2	NS	NS	NS	1.7	NS	1.6	0.8	4.6	1.4	NS	1.1	NS	0.6	1.9	NS	NS
Cd	%	0.7	NS	0.7	0.8	NS	1.1	NS	NS	NS	0.4	NS	0.6	0.7	0.7	0.5	NS	0.4	NS	0.2	0.5	NS	NS
Cr	%	1.0	NS	0.6	0.7	NS	[illegible]	NS	NS	NS	1.0	NS	0.5	0.2	1.1	0.6	NS	0.4	NS	0.2	0.4	NS	NS
Cu	%	0.3	NS	0.3	0.3	NS	0.4	NS	NS	NS	0.2	NS	0.3	0.03	0.09	0.1	NS	0.2	NS	0.02	0.1	NS	NS
Fe	%	0.23	NS	0.10	0.07	NS	0.14	NS	NS	NS	0.26	NS	0.14	0.33	0.65	0.12	NS	0.14	NS	0.31	0.17	NS	NS
Mn	%	1.05	NS	0.49	0.33	NS	1.31	NS	NS	NS	0.33	NS	1.07	1.36	4.27	0.88	NS	2.11	NS	1.40	1.05	NS	NS
Ni	%	< 1.9	NS	<1.5	< 1.3	NS	< 1.9	NS	NS	NS	2.1	NS	< 1.7	2.1	3.5	< 1.6	NS	< 1.3	NS	1.2	1.4	NS	NS
Pb	%	2.1	NS	2.3	1.9	NS	2.1	NS	NS	NS	1.0	NS	2.1	0.4	2.2	1.9	NS	2.1	NS	0.6	0.8	NS	NS
Zn	%	2.4	NS	0.8	0.9	NS	1.1	NS	NS	NS	1.3	NS	1.4	1.3	1.6	1.1	NS	0.7	NS	0.7	0.5	NS	NS

NS = no sample

Percentages are based on total concentration in dry sediment.

Table A-14: Sediment exchange data summary - May 1974 survey

Parameter	Units	Stations																					
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22
COD	%	NS	NS	0.60	NS	NS	NS	0.92	NS	3.2	0.19	NS	0.65	0.52	0.36	0.81	0.35	1.41	NS	0.37	0.45	0.34	NS
Kjeldahl-N	%	NS	NS	2.6	NS	NS	NS	1.0	NS	3.1	1.3	NS	5.2	3.8	3.0	1.9	3.0	5.1	NS	5.8	3.0	6.1	NS
NO_3-N	%	NS	NS	7.23	NS	NS	NS	8.67	NS	4.21	2.43	NS	4.48	1.46	4.93	24.7	5.62	27.8	NS	3.46	3.98	5.71	NS
Total-P	%	NS	NS	4.6	NS	NS	NS	1.0	NS	1.9	0.2	NS	1.9	0.5	2.0	0.7	3.4	3.5	NS	0.4	1.2	3.1	NS
Cd	%	NS	NS	1.0	NS	NS	NS	0.7	NS	0.6	1.2	NS	2.3	0.7	0.9	1.1	1.1	1.7	NS	0.5	0.5	1.1	NS
Cr	%	NS	NS	3.3	NS	NS	NS	1.6	NS	1.8	1.6	NS	0.8	1.4	2.2	1.3	7.8	16.9	NS	0.5	0.7	3.6	NS
Cu	%	NS	NS	0.2	NS	NS	NS	0.1	NS	0.1	0.02	NS	0.08	0.04	0.07	0.09	0.08	0.5	NS	0.02	0.06	0.2	NS
Fe	%	NS	NS	0.70	NS	NS	NS	0.25	NS	0.38	0.19	NS	0.23	0.10	0.71	0.32	0.43	3.50	NS	0.24	0.24	0.75	NS
Mn	%	NS	NS	0.81	NS	NS	NS	0.25	NS	0.50	0.81	NS	3.56	1.25	0.39	0.18	0.21	2.33	NS	1.27	1.33	0.30	NS
Ni	%	NS	NS	4.3	NS	NS	NS	2.0	NS	<2.1	2.2	NS	2.2	1.6	2.7	<1.5	<2.0	4.8	NS	1.6	<1.4	<4.0	NS
Pb	%	NS	NS	2.7	NS	NS	NS	3.0	NS	3.9	0.6	NS	1.1	0.2	1.9	2.0	1.5	4.0	NS	0.7	0.8	2.4	NS
Zn	%	NS	NS	[illegible]	NS	NS	NS	1.3	NS	1.3	0.3	NS	0.4	0.3	1.2	0.6	0.6	5.9	NS	0.4	0.5	1.2	NS

NS = no sample

Percentages are based on total concentration in dry sediment

APPENDIX B-1

DETROIT RIVER BENTHOS
November 1973

	14 A	14 B	15 A	15 B	17 B	18 A	18 B
Trichoptera							
Hydropsychidae							
Cheumatopsychae (Wallengren)							
Hydropsychae (Pictet)							
Macronemum (Burnmeister)							
Brachycentridae							
Brachycentrus (Curtis)							
Leptoceridae							
Athripsodes (Billberg)							
Acari							
Trombidiforme							
Parasitengona							
Hygrobatidae							
Hygrobates (Koch 1837)							
Ephemeroptera[1]							
Heptageniidae							
Stenonema ithaca							
Amphipoda							
Talitridae							
Hyalella azteca (Saussure)					4		
Gammaridae							
Gammarus fasciatus (Say)					9		
Gastropoda							
Pleuroceridae							
Goniobasis (Lea) sp. 1	2		6	3			
Goniobasis (Lea) sp. 2							
Planorbidae							
Helisoma (Swainson)	7	14	1				
Amnicolidae[2]							
Bithinia tentaculata L.							
Valvatidae							
Valvata sp.							
Physidae							
Physa (Draparnaud)					12	31	9
Lymnaeidae							
Lymnaea sp.							
Ancylidae							
Ferrissia (Walker)							
Pelecypoda							
Sphaeriidae							
Sphaerium (Scopoli)	1	1	2				
Pisidium (Pfeiffer				1			
Coelenterata							
Hydridae							
Hydra sp.							
Annelida							
Oligochaeta[3]							
Tubificidae							
Limnodrilus cervica	970	542	8	4	3		
Psammoryctides californianus	16	2		2			
Hirudinea[4]							
Erpobdellidae							
Dina microstoma	4						
Diptera[5]							
Chironomidae				6			
Tanypodinae							
Tanypus (Meigen)							
Porifera							
(5 x 3 mm)							
Turbellaria							
Macrostomida							
Macrostomidae							
Macrostomum (O. Schmidt)			3				
Taxa	6	4	5	5	4	1	1
Individuals	1000	559	20	16	30	31	9
$\bar{X}$ Biomass/m^2 (wet weight)	13.33		22.10		6.10	1.13	
$\bar{X}$ Individuals/m^2	14735		340		567	378	
Shannon-Weaver Diversity	0.16		0.43		1.23	0.00	
Richness ($\bar{X}$) (S-1/lnN)	0.68		1.37		0.90	0.00	
Richness ($\bar{X}$) ($S/\sqrt{N}$)	0.19		1.19		0.76	0.26	

APPENDIX B-1

DETROIT RIVER BENTHOS
November 1973

	19		20	
	A	B	A	B
Trichoptera				
Hydropsychidae				
Cheumatopsyche (Wallengren)				
Hydropsyche (Pictet)				
Macronemum (Burmeister)				
Brachycentridae				
Brachycentrus (Curtis)				
Leptoceridae				
Athripsodes (Billberg)				
Acari				
Trombidiforme				
Parasitengona				
Hygrobatidae				
Hygrobates (Koch 1837)				
Ephemeroptera[1]				
Heptageniidae				
Stenonema ithaca				
Amphipoda				
Talitridae				
Hyalella azteca (Saussure)				
Gammaridae				
Gammarus fasciatus (Say)				
Gastropoda				
Pleuroceridae				
Goniobasis (Lea) sp. 1				
Goniobasis (Lea) sp. 2				
Planorbidae				
Helisoma (Swainson)				
Amnicolidae[2]				
Bithynia tentaculata L.				
Valvatidae				
Valvata sp.	15	12	21	4
Physidae				
Physa (Draparnaud)	5	16		
Lymnaeidae				
Lymnaea sp.	9	23	2	17
Ancylidae				
Ferrissia (Walker)				
Pelecypoda				
Sphaeriidae				
Sphaerium (Scopoli)				
Pisidium Pfeiffer			5	
Coelenterata				
Hydridae				
Hydra sp.				
Annelida				
Oligochaeta[3]				
Tubificidae				
Limnodrilus cervix				
Psammoryctides californianus				
Hirudinea[4]				
Erpobdellidae				
Dina microstoma				
Diptera[5]				
Chironomidae			29	18
Tanypodinae				
Tanypus (Meigen)				
Porifera				
(3 x 3 mm)				
Turbellaria				
Macrostomida				
Macrostomidae				
Macrostomum (O. Schmidt)				
Taxa	3	3	4	3
Individuals	29	51	57	39
$\bar{X}$ Biomass/m^2 (wet weight)	37.92		5.82	
$\bar{X}$ Individuals/m^2	756		907	
Shannon-Weaver Diversity ($\bar{X}$)	1.04		1.00	
Richness ($\bar{X}$) (S-1/lnN)	0.55		0.66	
Richness ($\bar{X}$ (S/$\sqrt{N}$))	0.49		0.51	

APPENDIX B-1

DETROIT RIVER BENTHOS
November 1973

	6 A	6 B	7 A	7 B	8 A	8 B	9 A	9 B
Trichoptera								
Hydropsychidae								
Cheumatopsychae (Wallengren)	11	3	2	16			1	
Hydropsychae (Pictet)	7		5	10		1	2	2
Macronemum (Burnmeister)			126	42	1	1	6	2
Brachycentridae								
Brachycentrus (Curtis)			10					
Leptoceridae								
Athripsodes (Billberg)								
Acari								
Trombidiforme								
Parasitengona								
Hygrobatidae								
Hygrobates (Koch 1837)			1					
Ephemeroptera[2]								
Heptageniidae								
Stenonema ithaca								4
Amphipoda								
Talitridae								
Hyalella azteca (Saussure)			2					
Gammaridae								
Gammarus fasciatus (Say)			7	2	1			
Gastropoda								
Pleuroceridae								
Goniobasis (Lea) sp. 1				10	2	4		1
Goniobasis (Lea) sp. 2				3	3	1		1
Planorbidae								
Helisoma (Swainson)								
Amnicolidae[2]								
Bithynia tentaculata L.	1							
Valvatidae								
Valvata sp								
Physidae								
Physa (Draparnaud)								
Lymnaeidae								
Lymnaea sp								
Ancylidae								
Ferrissia (Walker)			1					
Pelecypoda								
Sphaeriidae								
Sphaerium (Scopoli)			1	1	1	2		
Pisidium (Pfeiffer)	1		2			1		
Coelenterata								
Hydridae								
Hydra sp								
Annelida								
Oligochaeta[3]								
Tubificidae								
Limnodrilus cervix			4	6				
Psammoryctides californianus								
Hirudinea[2]								
Erpobdellidae								
Dina microstoma					1			
Diptera[2]								
Chironomidae			24	7			1	
Tanypodinae								
Tanypus (Meigen)				2				
Porifera								
(5 x 3 mm)							1	
Turbellaria								
Macrostomida								
Macrostomidae								
Macrostomum (O. Schmidt)							3	
Taxa	4	1	12	9	6	7	6	5
Individuals	20	3	185	97	12	11	14	10
$\bar{X}$ Biomass g/m^2 (wet weight)	1.04		20.04		14.93		1.89	
$\bar{X}$ Individuals/m^2	217		2665		435		227	
Shannon-Weaver Diversity ($\bar{X}$)	0.50		1.47		1.74		1.51	
Richness ($\bar{X}$) (S-1/lnN)	0.79		1.93		2.26		1.82	
Richness ($\bar{X}$) ($S/\sqrt{N}$)	0.45		0.89		1.92		1.59	

APPENDIX B-1

DETROIT RIVER BENTHOS
November 1973

	1 A	1 B	2 A	2 B	3 A	3 B	5 A	5 B
Trichoptera								
Hydropsychidae								
Cheumatopsychae (Wallengren)								
Hydropsychae (Pictet)							56	21
Macronemum (Burnmeister)					2	1	19	41
Brachycentridae								
Brachycentrus (Curtis)								
Leptoceridae					1	1		2
Athripsodes (Billberg)								
Acari						5		
Trombidiforme								
Parasitengona								
Hygrobatidae								
Hygrobates(Koch 1837)								
Ephemeroptera[1]								
Heptageniidae								
Stenonema ithaca								
Amphipoda								
Talitridae								
Hyalella azteca (Saussure)								
Gammaridae							2	2
Gammarus fasciatus (Say)								
Gastropoda								4
Pleuroceridae								
Goniobasis (Lea) sp. 1	4	3	21	17	6			1
Goniobasis (Lea) sp. 2								
Planorbidae								
Helisoma (Swainson)								
Amnicolidae								
Bithinia tentaculata L.								
Valvatidae								
Valvata sp.								
Physidae								
Physa (Draparnaud)								
Lymnaeidae					2	1		
Lymnaea sp.								
Ancylidae								
Ferrissia (Walker)								
Pelecypoda								
Sphaeriidae								
Sphaerium (Scopoli)								
Pisidium (Pfeiffer)							1	2
Coelenterata								2
Hydridae								
Hydra sp.								
Annelida					2			
Oligochaeta[3]								
Tubificidae								
Limnodrilus cervica								
Psammoryctides californianus								
Hirudinea[4]						2	1	2
Erpobdellidae								
Dina microstoma								
Diptera								
Chironomidae								
Tanypodinae							24	18
Tanypus (Meigen)								
Porifera							8	
(5 x 3 mm)								
Turbellaria								
Macrostomida								
Macrostomidae								
Macrostomum (O. Schmidt)								
Taxa	1	1	1	1	5	5	7	11
Individuals	4	3	21	17	13	10	111	95
$\bar{X}$ Biomass/m^2 (wet weight)	11.5		62.00		19.28		6.62	
$\bar{X}$ Individuals/m^2	66		359		217		1947	
Shannon-Weaver Diversity ($\bar{X}$)	0.00		0.00		1.39		1.47	
Richness ($\bar{X}$) (S-1/lnN)	0.00		0.00		1.65		1.24	
Richness ($\bar{X}$) ($S/\sqrt{N}$)	0.50		0.22		1.49		0.45	

APPENDIX B-1

DETROIT RIVER
November 1973

	10 A	10 B	11 A	11 B	12 A	12 B	13 A	13 B
Trichoptera								
Hydropsychidae								
Cheumatopsychae (Wallengren)								
Hydropsychae (Pictet)					1			
Macronemum (Burnmeister)								
Brachycentridae								
Brachycentrus (Curtis)								
Leptoceridae								
Athripsodes (Billberg)								
Acari								
Trombidiforme								
Parasitengona								
Hygrobatidae								
Hygrobates (Koch 1837)								
Ephemeroptera[1]								
Heptageniidae								
Stenonema ithaca								
Amphipoda								
Talitridae								
Hyalella azteca (Saussure)				1				
Gammaridae								
Gammarus fasciatus (Sav)								
Gastropoda								
Pleuroceridae								
Goniobasis (Lea) sp. 1								
Goniobasis (Lea) sp. 2								
Planorbidae								
Helisoma (Swainson)	1	1		1				
Amniocolidae[2]								
Bithinia tentaculata L.								
Valvatidae								
Valvata sp.								
Physidae								
Physa (Draparnaud)								
Lymnaeidae								
Lymnaea sp.								
Ancylidae								
Ferrissia (Walker)								
Pelecypoda								
Sphaeriidae								
Sphaerium (Scopoli)	9	21						
Pisidium (Pfeiffer			1	4				
Coelenterata								
Hydridae								
Hydra sp.								
Annelida								
Oligochaeta[3]								
Tubificidae								
Limnodrilus cervica	5	8	17	12	1		14400	28900
Psammoryctides californianus	7	14	26	1	3	9	97	142
Hirudinea[4]								
Erpobdellidae								
Dina microstoma	6	9					2	17
Diptera[5]								
Chironomidae								
Tanypodinae								
Tanypus (Meigen)					69	103		
Porifera								
(5 x 3 mm)								
Turbellaria								
Macrostomida								
Macrostomidae								
Macrostomum (O. Schmidt)	8	16						
Taxa	6	6	3	5	4	2	3	3
Individuals	36	69	44	19	74	112	14499	29059
$\bar{X}$ Biomass/m^2 (wet weight)	31.10		1.66		2.54		133.70	
$\bar{X}$ Individuals/m^2	993		596		1753		411701	
Shannon-Weaver Diversity ($\bar{X}$)	1.64		0.92		0.30		0.04	
Richness ($\bar{X}$) (S-1/lnN)	1.29		0.95		0.48		0.20	
Richness ($\bar{X}$) (S/$\sqrt{N}$)	0.86		0.80		0.33		0.02	

APPENDIX B-2

DETROIT RIVER BENTHOS
May 1974

	13		14		15		16	
	a	b	a	b	a	b	a	b
Trichoptera								
Hydropsychidae								
Cheumatopsychae (Wallengren)								
Hydropsychae (Pictet)								
Brachycentridae								
Brachycentrus (Curtis)						1		
Leptoceridae								
Athripsodes (Billberg)								1
Acari								
Trombidiforme								
Parasitengona								
Hygrobatidae								
Hygrobates (Koch 1937)								
Ephemeroptera								
Ephemeridae								
Ephemera simulans (Walker)								
Hexagenia (Walsh)							9	2
Amphipoda								
Haustoriidae								
Pontoporeia affinis (Lindstrom)								
Gastropoda								
Pleuroceridae								
Goniobasis (Lea) sp. 1								
Goniobasis (Lea) sp. 2								
Planorbidae								
Helisoma (Swainson)	3			3				
Physidae								
Physa (Draparnaud)	1	5		1		2		
Amnicolidae								
Pyrgulopsis sp.								
Bithynia tentaculata (L.)	4	3	1					
Pelecypoda								
Sphaeriidae								
Sphaerium (Scopoli)								
Musculium (Pfeiffer)	1							
Annelida								
Oligochaeta								
Tubificidae								
Limnodrilus cervix	12297	5860	280			10		
Limnodrilus angustipenis	4102	1606					2	
Psammoryctides californianus		21						
Tubifex tubifex							3	9
Hirudinea								
Dina microstoma	139	138	1	18	1	21		
Hemiptera								
Corixidae (immature)								
Chironomidae								
Chironominae								
Tanytarsus (Van der Wulp)								
Chironomus (Meigen)								
Taxa	7	6	3	3	1	4	3	3
Individuals	16537	7693	282	22	1	34	14	12
$\bar{X}$ Biomass/m^2 (wet weight)	56.85		9.58		5.43		2.91	
$\bar{X}$ Individuals/m^2	229017		2873		330		246	
Shannon-Weaver Diversity ($\bar{X}$)	0.63		0.32		0.67		0.81	
Richness ($\bar{X}$) $S-1/\ln N$	0.59		0.50		0.43		0.78	
Richness ($\bar{X}$) $S/\sqrt{N}$	0.06		0.41		0.85		0.83	

APPENDIX B-2

DETROIT RIVER BENTHOS
May 1974

	9		10		11		12	
	a	b	a	b	a	b	a	b
Trichoptera								
Hydropsychidae								
Cheumatopsychae (Wallengren)		1						
Hydropsychae (Pictet)	3							
Brachycentridae								
Brachycentrus (Curtis)								
Leptoceridae								
Athripsodes (Billberg)								
Acari								
Trombidiforme								
Parasitengona								
Hygrobatidae								
Hygrobates (Koch 1937)								
Ephemeroptera								
Ephemeridae								
Ephemera simulans (Walker)								
Hexagenia (Walsh)								6
Amphipoda								
Haustoriidae								
Pontoporeia affinis (Lindstrom)							4	4
Gastropoda								
Pleuroceridae								
Goniobasis (Lea) sp. 1								
Goniobasis (Lea) sp. 2								
Planorbidae								
Helisoma (Swainson)								
Physidae								
Physa (Draparnaud)								
Amnicolidae								
Pyrgulopsis sp.								
Bithinia tentaculata (L.)								
Pelecypoda								
Sphaeriidae								
Sphaerium (Scopoli)			29	9				
Pisidium (Pfeiffer)			1					
Annelida								
Oligochaeta								
Tubificidae								
Limnodrilus cervix			99	15	1		102	55
Limnodrilus angustipenis							9	
Psammoryctides californianus								
Tubifex tubifex			21					
Hirudinea								
Dina microstoma			2	4		2		
Hemiptera								
Corixidae (immature)								1
Chironomidae								
Chironominae								
Tanytarsus (Van der Wulp)								1
Chironomus (Meigen)								
Taxa	1	1	5	3	1	1	3	5
Individuals	3	1	152	28	1	2	115	67
$\bar{X}$ Biomass/m^2 (wet weight)	0.39		9.44		0.86		11.98	
$\bar{X}$ Individuals/m^2	38		1701		28		1720	
Shannon-Weaver Diversity ($\bar{X}$)	0.00		0.97		0.00		0.55	
Richness ($\bar{X}$) S-1/lnN	0.00		0.70		0.00		0.[illegible]	
Richness ($\bar{X}$) S/$\sqrt{N}$	0.34		0.49		0.85		[illegible]45	

APPENDIX B-2

DETROIT RIVER BENTHOS
May 1974

	1		2		3		4	
	a	b	a	b	a	b	a	b
Trichoptera								
Hydropsychidae								
Cheumatopsyche (Wallengren)								2
Hydropsyche (Pictet)					1		4	1
Brachycentridae								
Brachycentrus (Curtis)								
Leptoceridae								
Athripsodes (Billberg)								
Acari								
Trombidiforme								
Parasitengona								
Hygrobatidae								
Hygrobates (Koch 1937)								
Ephemeroptera								
Ephemeridae								
Ephemera simulans (Walker)								
Hexagenia (Walsh)								
Amphipoda								
Haustoriidae								
Pontoporeia affinis (Lindstrom)								
Gastropoda								
Pleuroceridae								
Goniobasis (Lea) sp. 1	2	1	9	23	6	2	25	20
Goniobasis (Lea) sp. 2								
Planorbidae								
Helisoma (Swainson)								
Physidae								
Physa (Draparnaud)					1	2		
Amnicolidae								
Pyrgulopsis sp.								
Bithynia tentaculata (L.)								
Pelecypoda								
Sphaeriidae								
Sphaerium (Scopoli)								
Pisidium (Pfeiffer)								
Annelida								
Oligochaeta								
Tubificidae								
Limnodrilus cervix								
Limnodrilus angustipenis								
Psammoryctides californianus								
Tubifex tubifex								
Hirudinea								
Dina microstoma								
Hemiptera								
Corixidae (immature)								
Chironomidae								
Chironominae								
Tanytarsus (Van der Wulp)								
Chironomus (Meigen)								
Taxa	1	1	1	1	3	2	2	3
Individuals	2	1	9	23	8	4	29	23
$\bar{X}$ Biomass/m^2 (wet weight)	4.30		58.10		12.00		52.00	
$\bar{X}$ Individuals/m^2	28		302		113		491	
Shannon-Weaver Diversity ($\bar{X}$)	0.00		0.00		0.71		0.44	
Richness ($\bar{X}$) $S-1/\ln N$	0.00		0.00		0.84		0.47	
Richness ($\bar{X}$) $S/\sqrt{N}$	0.85		0.27		1.03		0.50	

APPENDIX B-2

DETROIT RIVER BENTHOS
May 1974

	5		6		7		8	
	a	b	a	b	a	b	a	b
Trichoptera								
Hydropsychidae								
Cheumatopsychae (Wallengren)			7	4	1	3	1	
Hydropsychae (Pictet)	7	12	18	10	10	4	1	
Brachycentridae								
Brachycentrus (Curtis)								
Leptoceridae								
Athripsodes (Billberg)								
Acari								
Trombidiforme								
Parasitengona								
Hygrobatidae								
Hygrobates (Koch 1937)								
Ephemeroptera								
Ephemeridae								
Ephemera simulans (Walker)								
Hexagenia (Walsh)								2
Amphipoda								
Haustoriidae								
Pontoporeia affinis (Lindstrom)			1	1			1	1
Gastropoda								
Pleuroceridae								
Goniobasis (Lea) sp. 1	1							
Goniobasis (Lea) sp. 2								
Planorbidae								
Helisoma (Swainson)	1							
Physidae								
Physa (Draparnaud)								
Amnicolidae								
Pyrgulopsis sp.								
Bithinia tentaculata (L.)								
Pelecypoda								
Sphaeriidae								
Sphaerium (Scopoli)								
Pisidium (Pfeiffer)								
Annelida								
Oligochaeta								
Tubificidae								
Limnodrilus cervica								
Limnodrilus angustipenis								
Psammoryctides californianus								
Tubifex tubifex								
Hirudinea								
Dina microstoma								
Hemiptera								
Corixidae (immature)								
Chironomidae								
Chironominae								
Tanytarsus (Van der Wulp)								
Chironomus (Meigen)								
Taxa	3	1	3	3	2	2	3	2
Individuals	9	12	26	15	11	7	3	3
$\bar{X}$ Biomass/m^2 (wet weight)	3.65		11.15		10.51		0.40	
$\bar{X}$ Individuals/m^2	198		188		170		57	
Shannon-Weaver Diversity ($\bar{X}$)	0.34		0.77		0.49		0.87	
Richness ($\bar{X}$) S-1/lnN	0.46		0.68		0.47		1.37	
Richness ($\bar{X}$) $S/\sqrt{N}$	0.64		0.68		0.68		1.44	

APPENDIX B-2

DETROIT RIVER BENTHOS
May 1974

	17 a	17 b	18 a	18 b	21 a	21 b	22 a	22 b
Trichoptera								
Hydropsychidae								
Cheumatopsyche (Wallengren)								
Hydropsyche (Pictet)								
Brachycentridae								
Brachycentrus (Curtis)								
Leptoceridae								
Athripsodes (Billberg)								
Acari								
Trombidiformes								
Parasitengona								
Hygrobatidae								
Hygrobates (Koch 1937)								
Ephemeroptera								
Ephemeridae								
Ephemera simulans (Walker)								
Hexagenia (Walsh)		1			3	7		
Amphipoda								
Haustoriidae								
Pontoporeia affinis (Lindstrom)	4	2						
Gastropoda								
Pleuroceridae								
Goniobasis (Lea) sp. 1								
Goniobasis (Lea) sp. 2								
Planorbidae								
Helisoma (Swainson)								
Physidae								
Physa (Draparnaud)			7					
Amnicolidae								
Pyrgulopsis sp		1						
Bithynia tentaculata (L.)					1			
Pelecypoda								
Sphaeriidae								
Sphaerium (Scopoli)					5	4		2
Pisidium (Pfeiffer)					13	3	1	1
Annelida								
Oligochaeta								
Tubificidae								
Limnodrilus cervix		3	4			1		
Limnodrilus angustipenis		1			4	1		
Psammoryctides californianus						12		
Tubifex tubifex								
Hirudinea								
Dina microstoma			1					
Hemiptera								
Corixidae (immature)								
Chironomidae								
Chironominae								
Tanytarsus (Van der Wulp)								
Chironomus (Meigen)		1			2			
Taxa	1	6	3	0	6	6	1	2
Individuals	4	9	12	0	28	28	1	3
$\bar{X}$ Biomass/m^2 (wet weight)	0.94		1.56		9.39		5.42	
$\bar{X}$ Individuals/m^2	123		226		529		38	
Shannon-Weaver Diversity ($\bar{X}$)	0.84		0.87		1.48		0.32	
Richness ($\bar{X}$) S-1/lnN	1.14		0.80		1.50		0.46	
Richness ($\bar{X}$) S/$\sqrt{N}$	0.35		0.87		1.13		1.08	

Appendix C-1
Detroit River Phytopigments - Chlorophylls a, b, and c (μg/l) November 1973 and May 1974

Sample Number	November 1973 Chl. a	November 1973 Chl. b	November 1973 Chl. c	May 1974 Chl. a	May 1974 Chl. b	May 1974 Chl. c
1A	1.0	0.4	1.3	1.8	0.2	0.9
1B	1.4	0.6	1.2	2.3	0.8	3.2
2A	1.3	0.3	1.1	0.4	0.0	0.2
2B	1.0	0.9	2.3	1.2	0.0	1.1
3A	1.2	0.4	1.2	0.4	0.0	0.2
3B	0.5	0.1	0.9	1.7	0.2	1.0
4A	1.5	0.1	1.2	1.6	0.5	2.3
4B	1.2	0.2	0.8	0.9	0.3	1.0
5A	1.1	0.2	0.9	4.0	0.6	2.2
5B	1.7	0.3	1.3	3.6	0.8	2.3
6A	0.7	0.1	-0.1	2.7	0.7	2.5
6B	0.6	0.7	0.9	1.2	0.4	1.4
7A	3.5	0.5	1.6	-	-	-
7B	1.3	0.3	1.2	-	-	-
19A	1.5	0.4	1.4	2.4	0.8	3.3
19B	1.0	0.1	0.6	2.1	0.5	1.8
20A	0.6	0.4	1.7	4.0	0.8	3.0
20B	1.9	1.3	3.6	3.7	0.6	2.0
21A	1.9	0.4	1.6	2.5	0.4	1.6
21B	1.7	0.1	0.9	1.1	0.1	1.1
22A	3.4	0.4	0.9	2.7	0.5	1.3
22B	2.7	0.5	1.4	2.3	0.3	1.3

APPENDIX C-2
PHYTOPLANKTON SUMMARY

	St. Clair River							Detroit River			
	1	2	3	4	5	6	7	19	20	21	22
August 1973											
Total Species (S)	31	20	41	22	28	28	31	64	69	32	-
Mean total individuals/ ml (N)	400	527	345	298	9695	277	427	2018	5209	1197	-
Richness ($S/\sqrt{N}$)	1.55	0.87	2.21	1.27	0.28	1.68	1.50	1.42	0.96	0.92	-
Richness (S-1/lnN)	5.01	3.03	6.85	3.69	2.94	4.80	4.95	8.28	7.95	4.37	-
Diversity ($\bar{d}$)	2.65	2.51	2.90	2.71	1.29	2.59	2.89	2.43	1.93	2.17	-
November 1973											
Total Species (S)	33	36	43	42	43	51	52	52	41	29	45
Mean total individuals/ ml (N)	601	526	741	715	682	948	1147	963	803	944	1052
Richness ($S/\sqrt{N}$)	1.35	1.57	1.58	1.57	1.65	1.66	1.54	1.68	1.45	0.94	9.39
Richness (S-1/lnN)	5.00	5.59	6.36	6.24	6.44	7.29	7.24	7.42	5.98	4.09	6.32
Diversity ($\bar{d}$)	2.53	2.82	2.90	2.82	3.12	2.86	3.94	2.97	2.64	2.43	3.08
Mean Chlorophyll a (µg/l)	1.2	1.2	0.8	1.4	1.4	0.6	2.4	1.2	1.2	1.8	3.0
May 1974											
Total Species (S)	34	36	33	35	38	39	-	47	53	38	37
Mean total individuals/ ml (N)	1700	1346	1113	1385	3132	1416	-	3208	3032	2174	1899
Richness ($S/\sqrt{N}$)	0.82	0.98	0.99	0.94	0.68	1.04	-	0.83	0.96	0.81	0.85
Richness (S-1/lnN)	4.44	4.86	4.56	4.70	4.60	5.24	-	5.70	5.49	4.81	4.77
Diversity ($\bar{d}$)	2.63	2.61	2.71	2.55	2.76	2.64	-	2.68	2.97	2.72	2.54
Mean Chlorophyll a (µg/l)	2.0	0.8	1.0	1.2	3.8	2.0	-	2.2	3.8	1.8	2.5

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
August 1973

	1	2*	3	4*
Cyanophyta:				
Anabaena flos-aquae (Lyngb.) DeBrebisson			6	1
A. scheremetievi Elenkin				
A. spiroides var. *crassa* Lemm.	2			
Anabaenopsis elenkinii Miller				
Aphanocapsa elachista West & West				
Aphanothece gelatinosa (Henn.) Lemm.	2			
A. microspora (Menegh.) Rabenhorst	2			
Arthrospira gomontiana Setchell				
Chroococcus dispersus (Keissl.) Lemm.			2	15
C. limneticus Lemm.				
C. turgidus (Kuetz.) Naegeli				
Coelosphaerium naegelianum Unger				
Cyanarcus hamiformis Pascher	2			
Dactylococcopsis acicularis Lemm.			2	
D. fascicularis Lemm.	2			
D. rhaphidioides Hansgirg			2	
D. smithii Chodat & Chodat				
Lyngbya sp. Agardh				
L. limnetica Lemm.		7		7
Marssoniella elegans Lemm.				
Merismopedia glauca (Ehr.) Naegeli				
M. tenuissima Lemm.				
Microcystis aeruginosa Kuetz.	8		2	
Oscillatoria sp. Vaucher			3	
O. agardhii Gomont				
O. angusta Koppe				
O. hamelii Fremy				
O. limnetica Lemm.				
O. minima Gicklhorn				
Pelogloea bacillifera Lauterborn	35	18	9	15
Rhaphidiopsis curvata Fritsch & Rich				
Chlorophyta:				
Actinastrum hantzschii var. *fluviatile* Schroeder				
Ankistrodesmus braunii (Naeg.) Brunnthaler				
A. convolutus Corda				
A. falcatus (Corda) Ralfs			6	
A. spiralis (Turner) Lemm.			2	
Characium falcatum Schroeder				
C. limneticum Lemm.				
Chariopsis longissima Lemm.				
Chlorella vulgaris Beyerinck	39	114		37
Chlorococcum humicola (Naeg.) Rabenhorst				
Closteriopsis longissima var. *tropica* West & West				
Closterium sp. Nitzsch			2	
Coelastrum cambricum Archer				
C. microporum Naegeli *in* A. Braun				
C. scabrum Reinsch				
C. sphaericum Naegeli				
Cosmarium sp. Corda				
Crucigenia quadrata Morren	4			

continued

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate sample)
August 1973

	1	2*	3	4*
C. tetrapedia (Kirch.) West & West		22	6	
Elakatothrix gelatinosa Wille	4	30	6	15
Golenkinia radiata (Chod.) Wille	4			
Kirchneriella elongata G. M. Smith				
K. subsolitaria G. S. Smith				
Lagerheimia ciliata (Lag.) Chodat				
L. longiseta (Lemm.) Printz				
L. quadriseta (Lemm.) G. M. Smith	2			
L. subsala Lemm.				
Mougeotia sp. (C.A. Agardh) Wittrock		4		
Nephrocytium agardhianum Naegeli				
Oedogonium sp. Link				
Oocystis gloeocystiformis Borge				
O. lacustris Chodat				
O. novae-semliae Wille	2			
O. pusilla Hansgirg				
O. submarina Lagerheim				
Pediastrum boryanum (Turp.) Meneghini				
P. duplex var. *clathratum* (A. Braun) Lagerheim				
P. simplex var. *duodenarium* (Bailey) Rabenhorst				
P. tetras (Ehr.) Ralfs				
Phymatodocis sp. Nordstedt				
Planktosphaeria gelatinosa G. M. Smith			6	4
Pleurotaenium sp. Naegeli				
Rhizoclonium sp. Kuetz.				
Scenedesmus abundans (Kirch.) Chodat		4	2	
S. bijuga (Turp.) Lagerheim				
S. denticulatus Lagerheim				
S. dimorphus (Turp.) Kuetz.		7		
S. incrassatulus Bohlin				
S. opoliensis P. Richter				
S. quadricauda (Turp.) de Brebisson				
Schroederia setigera Lemm.		7		
Selenastrum minutum (Naeg.) Collins	15	15	8	4
S. westii G. M. Smith				
Staurastrum sp. Meyen				
Tetradesmus wisconsinense G. M. Smith				
Tetraedron caudatum (Corda) Hansgirg				
T. duospinum Ackley				
T. lunula (Reinsch) Wille			2	
T. minimum (A. Braun) Hansgirg				
T. regulare Kuetz.				
T. trigonum var. *gracile* (Reinsch) Detoni				
Tetraspora lacustris Lemm.		4		
Tetrastrum staurogeniaeforme (Schroeder) Lemm.				
Treubaria triappendiculata Bernard				
Ulothrix sp. Keutz.				
Chrysophyta:				
Diceras phaseolus Fott				4
Dinobryon sp. Ehr.			4	
D. bavaricum Imhof	4	18	11	7
D. calciformis Bach.				
D. divergens Imhof	4		2	
D. sertularia Ehr.				
D. tabellariae (Lemm.) Pascher in Pascher & Lemm.				
Kephyrion ovum Pascher			4	
Lagynion ampullaceum (Stokes) Pascher				
Mallomonas acaroides Perty				

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
August 1973

continued

	1	2*	3	4*
M. caudata Iwanoff				
M. urnaformis Prescott			2	
Ophiocytium capitatum Wolle				
Synura uvella Ehr.	2		2	4
Bacillariophyta:				
Achnanthes spp. Bory		26	2	
Amphora sp. Ehr.				
Asterionella formosa Hassall	21		19	7
Chaetoceras sp. Ehr.				
Cocconeis sp. Ehr.			4	
Coscinodiscus rothii (Ehr.) Grun.				
Cyclotella spp. Kuetz.	113	63	109	55
C. catenata Brun.				
Cymatopleura solea (Breb.) W. Smith				
Cymbella spp. Agardh			2	11
Diatoma tenue var. elongatum (Lyngb.)				
D. vulgare Bory				
Diploneis sp. Ehr.				
Epithemia zebra (Ehr.) Kuetz.				
Fragilaria spp. Lyngbye	15		15	
F. brevistriata var. inflata (Pant) Hust.				
F. capucina Desm.				
F. crotonensis Kitton		22	8	26
F. inflata				
F. pinnata Ehr.				
Gomphonema spp. Agardh				
Gyrosigma sp. Hassall				
Melosira granulata (Ehr.) Ralfs				
M. islandica O. Muell.				
M. italica (Ehr.) Kuetz.				
M. varians C. A. Ag.				
Navicula spp. Bory	4	7	2	4
N. pupula Kuetz.			2	
N. tripunctata (O. F. Muell) Bory				
Nitzschia spp. Hassall			2	
N. acicularis W. Smith				
N. dissipata (Kuetz.) Grun.				
N. frustulum Kuetz.				
N. linearis W. Smith				
N. palea (Kuetz.) W. Smith				4
N. sigmoidea (Ehr.) W. Smith				
N. tryblionella Hantzsch				
Opephora martyi Heribaud				
Pinnularia sp. Ehr.				
Rhizosolenia eriensis H. L. Smith				
Rhoicosphenia curvata (Kuetz.) Grun.			2	
Rhopalodia gibba (Ehr.) O. Muell.	2			
Stephanodiscus astraea (Ehr.) Grun.	19	30	20	30
Surirella sp. Turpin				
Synedra spp. Ehr.	43		4	7
S. actinastroides Lemm.				
S. ulna (Nitz.) Ehr.				
Tabellaria flocculosa (Roth) Kuetz.	19	96	26	22

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
August 1973

continued	1	2*	3	4*
Pyrrhophyta:				
Ceratium hirundinella (O. F. Muell.) Dujardin	4			
Glenodinium penardiforme (Linde.) Schiller	4	7	4	4
G. pulvisculus (Ehr.) Stein				
Euglenophyta:				
Colacium arbuscula Stein				
Euglena sp. Ehr.				
Trachelomonas sp. Ehr.			2	
T. robusta Swirenko				
T. volvocina Ehr.				
Other Flagellates:				
Chroomonas sp. Hansgirg	4			
Chrysococcus sp. Klebs				
Cryptomonas sp. Ehr.	6		9	
Nephroselmis olivacea Stein	4	26	9	15
Rhodomonas lacustris Pascher	9		13	
Total Number of Species (S)	31	20	41	22
Mean Total Individuals/ml (N)	400	527	345	298
Richness ($S/\sqrt{N}$)	1.55	0.87	2.21	1.27
Richness ($S-1/\ln N$)	5.01	3.03	6.85	3.69
Shannon-Weaver Diversity ($\bar{d}$)	2.65	2.51	2.90	2.71

*indicates single samples rather than replicates

DETROIT RIVER PHYTOPLANKTON

(mean number of individuals/ml from replicate samples)

August 1973

Cyanophyta:	5*	6	7*	19	20	21*	22**
Anabaena flos-aquae (Lyngb.) DeBrebisson							
A. scheremetievi Elenkin				2	8		
A. spiroides var. crassa Lemm.	49						
Anabaenopsis elenkinii Miller					4		
Aphanocapsa elachista West & West							
Aphanothece gelatinosa (Henn.) Lemm.							
A. microspora (Menegh.) Rabenhorst					48		
Arthrospira gomontiana Setchell				4			
Chroococcus dispersus (Keissl.) Lemm.	25		4	2			
C. limneticus Lemm.							
C. turgidus (Kuetz.) Naegeli							
Coelosphaerium naegelianum Unger							
Cyanarcus hamiformis Pascher	123			56	70	22	
Dactylococcopsis acicularis Lemm.				52			
D. fascicularis Lemm.							
D. rhaphidioides Hansgirg			7	17	83		
D. smithii Chodat & Chodat				41	26		
Lyngbya sp. Agardh							
L. limnetica Lemm.							
Marssoniella elegans Lemm.	480			72	26		
Merismopedia glauca (Ehr.) Naegeli							
M. tenuissima Lemm.		4	11	9	30		
Microcystis aeruginosa Kuetz.				4	10		
Oscillatoria sp. Vaucher				2			
O. agardhii Gomont					20		
O. angusta Koppe		7		4	5		
O. hamelii Fremy							
O. limnetica Lemm.		48		6	4	22	
O. minima Gicklhorn							
Pelogloea bacillifera Lauterborn					2		
Rhaphidiopsis curvata Fritsch & Rich							
Chlorophyta:							
Actinastrum hantzschii var. fluviatile Schroeder				8	39		
Ankistrodesmus braunii (Naeg.) Brunnthaler							
A. convolutus Corda							
A. falcatus (Corda) Ralfs	111	12	30	23	45	9	
A. spiralis (Turner) Lemm.	418	6	7	100	113	77	
Characium falcatum Schroeder				2			
C. limneticum Lemm.	86	4	4	17	26	11	
Chariopsis longissima Lemm.	37						
Chlorella vulgaris Beyerinck				11			
Chlorococcum humicola (Naeg.) Rabenhorst					8		
Closteriopsis longissima var. tropica West & West							
Closterium sp. Nitzsch							
Coelastrum cambricum Archer					4		
C. microporum Naegeli in A. Braun							
C. scabrum Reinsch					2		
C. sphaericum Naegeli				2			
Cosmarium sp. Corda							
Crucigenia quadrata Morren							

continued

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)

	August 1973						
	5*	6	7*	19	20	21*	22**
C. tetrapedia (Kirch.) West & West		2		2		4	
Elakatothrix gelatinosa Wille	25				4	4	
Golenkinia radiata (Chod.) Wille				2		7	
Kirchneriella elongata G. M. Smith				2			
K. subsolitaria G. S. Smith				6	2		
Lagerheimia ciliata (Lag.) Chodat				8	10		
L. longiseta (Lemm.) Printz							
L. quadriseta (Lemm.) G. M. Smith				10			
L. subsala Lemm.							
Mougeotia sp. (C.A. Agardh) Wittrock		2					
Nephrocytium agardhianum Naegeli							
Oedogonium sp. Link	62			2			
Oocystis gloeocystiformis Borge							
O. lacustris Chodat							
O. novae-semliae Wille							
O. pusilla Hansgirg					4	4	
O. submarina Lagerheim							
Pediastrum boryanum (Turp.) Meneghini			4				
P. duplex var. clathratum (A. Braun) Lagerheim	49	2	4	6	2		
P. simplex var. duodenarium (Bailey) Rabenhorst					2		
P. tetras (Ehr.) Ralfs					2		
Phymatodocis sp. Nordstedt				2			
Planktosphaeria gelatinosa G. M. Smith	49	4	4	18	67	4	
Pleurotaenium sp. Naegeli							
Rhizoclonium sp. Kuetz.					15		
Scenedesmus abundans (Kirch.) Chodat	62	3		23	13	4	
S. bijuga (Turp.) Lagerheim		7	7	11	21	11	
S. denticulatus Lagerheim	25	2	4	7	6		
S. dimorphus (Turp.) Kuetz.	25		4	2			
S. incrassatulus Bohlin					4		
S. opoliensis P. Richter							
S. quadricauda (Turp.) de Brebisson	111		4	26	41	11	
Schroederia setigera Lemm.	49			6	2		
Selenastrum minutum (Naeg.) Collins	332	11	7	55	179	30	
S. westii G. M. Smith				4			
Staurastrum sp. Meyen					2		
Tetradesmus wisconsinense G. M. Smith							
Tetraedron caudatum (Corda) Hansgirg							
T. duospinum Ackley					2		
T. lunula (Reinsch) Wille				21			
T. minimum (A. Braun) Hansgirg							
T. regulare Kuetz.			4	2			
T. trigonum var. gracile (Reinsch) Detoni					2	4	
Tetraspora lacustris Lemm.							
Tetrastrum staurogeniaeforme (Schroeder) Lemm.							
Treubaria triappendiculata Bernard	12			2	6		
Ulothrix sp. Keutz.					2		
Chrysophyta							
Diceras phaseolus Fott					2		
Dinobryon sp. Ehr.					2		
D. bavaricum Imhof	12	22	11		13	33	
D. calciformis Bach				9			
D. divergens Imhof		3			21		
D. sertularia Ehr.							
D. tabellariae (Lemm.) Pascher in Pascher & Lemm.							
Kephyrion ovum Pascher							
Lagynion ampullaceum (Stokes) Pascher				2			
Mallomonas acaroides Perty		4			2		

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
August 1973

continued	5*	6	7*	19	20	21*	22**
M. caudata Iwanoff	12						
M. urnaformis Prescott							
Ophiocytium capitatum Wolle							
Synura uvella Ehr.							
Bacillariophyta:							
Achnanthes spp. Bory			33	2	6	4	
Amphora sp. Ehr.			4	2	8		
Asterionella formosa Hassall	25			17	2		
Chaetoceras sp. Ehr.					2		
Cocconeis sp. Ehr.			4	4	10	4	
Coscinodiscus rothii (Ehr.) Grun.							
Cyclotella spp. Kuetz.	7134	75	4	167	1918	553	
C. catenata Brun.			7	961	1992	37	
Cymatopleura solea (Breb.) W. Smith							
Cymbella spp. Agardh				2			
Diatoma tenue var. elongatum (Lyngb.)							
D. vulgare Bory		2					
Diploneis sp. Ehr.						4	
Epithemia zebra (Ehr.) Kuetz.							
Fragilaria spp. Lyngbye		2	4	17	4	37	
F. brevistriata var. inflata (Pant) Hust.							
F. capucina Desm.							
F. crotonensis Kitton			30		9	18	
F. inflata							
F. pinnata Ehr.							
Gomphonema spp. Agardh				8	2	4	
Gyrosigma sp. Hassall							
Melosira granulata (Ehr.) Ralfs							
M. islandica O. Muell.							
M. italica (Ehr.) Kuetz.	209	2	66	79	92	184	
M. varians C. A. Ag.							
Navicula spp. Bory	25	10	41	4	9	11	
N. pupula Kuetz.						7	
N. tripunctata (O. F. Muell) Bory							
Nitzschia spp. Hassall	111		55	41	21	7	
N. acicularis W. Smith							
N. dissipata (Kuetz.) Grun.				2			
N. frustulum Kuetz.							
N. linearis W. Smith				6			
N. palea (Kuetz.) W. Smith		2	41		59		
N. sigmoidea (Ehr.) W. Smith							
N. tryblionella Hantzsch							
Opephora martyi Heribaud			7				
Pinnularia sp. Ehr.							
Rhizosolenia eriensis H. L. Smith							
Rhoicosphenia curvata (Kuetz.) Grun.				2			
Rhopalodia gibba (Ehr.) O. Muell.							
Stephanodiscus astraea (Ehr.) Grun.			7	23	17	26	
Surirella sp. Turpin							
Synedra spp. Ehr.		19	4	9	17	15	
S. actinastroides Lemm.					4		
S. ulna (Nitz.) Ehr.		1		2			
Tabellaria flocculosa (Roth) Kuetz.				2	4		

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals from replicate samples)
August 1973

continued	5*	6	7*	19	20	21*	22**
Pyrrhophyta:							
Ceratium hirundinella (O. F. Muell.) Dujardin				2	2		
Glenodinium penardiforme (Linde.) Schiller							
G. pulvisculus (Ehr.) Stein			4				
Euglenophyta:							
Colacium arbuscula Stein							
Euglena sp. Ehr.		2					
Trachelomonas sp. Ehr.							
T. robusta Swirenko							
T. volvocina Ehr.							
Other Flagellates:							
Chroomonas sp. Hansgirg							
Chrysococcus sp. Klebs					2		
Cryptomonas sp. Ehr.					2		
Nephroselmis olivacea Stein		3					
Rhodomonas lacustris Pascher	25	16		2	22	18	
Total Number of Species (S)	28	28	31	64	69	32	
Mean Total Individuals/ml (N)	9695	277	427	2018	5209	1197	
Richness ($S/\sqrt{N}$)	0.28	1.68	1.50	1.42	0.96	0.92	
Richness ($S-1/\ln N$)	2.94	4.80	4.95	8.28	7.95	4.37	
Shannon-Weaver Diversity ($\bar{d}$)	1.29	2.59	2.89	2,43	1,93	2.17	

*indicates single samples rather than replicates

**no samples from this station

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)

November 1973

	1	2	3	4
Cyanophyta:				
Anabaena flos-aquae (Lyngb.) DeBrebisson				
A. scheremetievi Elenkin				
A. spiroides var. crassa Lemm.				
Anabaenopsis elenkinii Miller				
Aphanocapsa elachista West & West	63			
Aphanothece gelatinosa (Henn.) Lemm.				
A. microspora (Menegh.) Rabenhorst				
Arthrospira gomontiana Setchell				
Chroococcus dispersus (Keissl.) Lemm.	11		30	8
C. limneticus Lemm.	4			
C. turgidus (Kuetz.) Naegeli		9	4	11
Coelosphaerium naegelianum Unger	9	11	6	2
Cyanarcus hamiformis Pascher	2			
Dactylococcopsis acicularis Lemm.				
D. fascicularis Lemm.				
D. rhaphidioides Hansgirg				
D. smithii Chodat & Chodat				
Lyngbya sp. Agardh				4
L. limnetica Lemm.		7	8	10
Marssoniella elegans Lemm.				
Merismopedia glauca (Ehr.) Naegeli				
M. tenuissima Lemm.				
Microcystis aeruginosa Kuetz.	17	61	52	34
Oscillatoria sp. Vaucher				
O. agardhii Gomont	10	11		6
O. angusta Koppe				4
O. hamelii Fremy				
O. limnetica Lemm.				
O. minima Gicklhorn				
Pelogloea bacillifera Lauterborn	26	2	70	
Rhaphidiopsis curvata Fritsch & Rich				
Chlorophyta:				
Actinastrum hantzschii var. fluviatile Schroeder				
Ankistrodesmus braunii (Naeg.) Brunnthaler				
A. convolutus Corda				
A. falcatus (Corda) Ralfs		32	11	8
A. spiralis (Turner) Lemm.		2		
Characium falcatum Schroeder				
C. limneticum Lemm.				
Chariopsis longissima Lemm.				
Chlorella vulgaris Beyerinck				
Chlorococcum humicola (Naeg.) Rabenhorst				
Closteriopsis longissima var. tropica West & West		2	2	
Closterium sp. Nitzsch				
Coelastrum cambricum Archer				
C. microporum Naegeli in A. Braun				
C. scabrum Reinsch				
C. sphaericum Naegeli				
Cosmarium sp. Corda		2	2	2
Crucigenia quadrata Morren			15	8

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
November 1973

continued	1	2	3	4
C. tetrapedia (Kirch.) West & West				
Elakatothrix gelatinosa Wille				
Golenkinia radiata (Chod.) Wille	4	13	10	11
Kirchneriella elongata G. M. Smith				2
K. subsolitaria G. S. Smith				
Lagerheimia ciliata (Lag.) Chodat				
L. longiseta (Lemm.) Printz				
L. quadriseta (Lemm.) G. M. Smith				
L. subsala Lemm.				
Mougeotia sp. (C. A. Agardh) Wittrock	2			
Nephrocytium agardhianum Naegeli				
Oedogonium sp. Link		2		
Oocystis gloeocystiformis Borge				4
O. lacustris Chodat	10		8	4
O. novae-semliae Wille		7	2	2
O. pusilla Hansgirg				
O. submarina Lagerheim	2		6	6
Pediastrum boryanum (Turp.) Meneghini				
P. duplex var. clathratum (A. Braun) Lagerheim				
P. simplex var. duodenarium (Bailey) Rabenhorst				
P. tetras (Ehr.) Ralfs				
Phymatodocis sp. Nordstedt				
Planktosphaeria gelatinosa G. M. Smith				
Pleurotaenium sp. Naegeli				
Polyblepharides sp. Dangeard.			2	
Rhizoclonium sp. Kuetz.				
Scenedesmus abundans (Kirch.) Chodat				
S. bijuga (Turp.) Lagerheim		2	2	2
S. denticulatus Lagerheim				
S. dimorphus (Turp.) Kuetz.	2		2	2
S. incrassatulus Bohlin				
S. opoliensis P. Richter				
S. quadricauda (Turp.) de Brebisson	2		2	
Schroederia setigera Lemm.		2	2	2
Selenastrum minutum (Naeg.) Collins			2	
S. westii G. M. Smith	4	4	2	2
Staurastrum sp. Meyen				
Tetradesmus wisconsinense G. M. Smith				
Tetraedron caudatum (Corda) Hansgirg				
T. duospinum Ackley	2			
T. lunula (Reinsch) Wille				
T. minimum (A. Braun) Hansgirg				
T. regulare Kuetz.			4	
T. trigonum var. gracile (Reinsch) Detoni				
Tetraspora lacustris Lemm.				
Tetrastrum staurogeniaeforme (Schroeder) Lemm.				
Treubaria triappendiculata Bernard				
Ulothrix sp. Kuetz.				
Chrysophyta:				
Diceras phaseolus Fott				
Dinobryon sp. Ehr.	4	2		

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)

November 1973

	1	2	3	4
Cyanophyta:				
Anabaena flos-aquae (Lyngb.) DeBrebisson				
A. scheremetievi Elenkin				
A. spiroides var. crassa Lemm.				
Anabaenopsis elenkinii Miller				
Aphanocapsa elachista West & West	63			
Aphanothece gelatinosa (Henn.) Lemm.				
A. microspora (Menegh.) Rabenhorst				
Arthrospira gomontiana Setchell				
Chroococcus dispersus (Keissl.) Lemm.	11		30	8
C. limneticus Lemm.	4			
C. turgidus (Kuetz.) Naegeli		9	4	11
Coelosphaerium naegelianum Unger	9	11	6	2
Cyanarcus hamiformis Pascher	2			
Dactylococcopsis acicularis Lemm.				
D. fascicularis Lemm.				
D. rhaphidioides Hansgirg				
D. smithii Chodat & Chodat				
Lyngbya sp. Agardh				4
L. limnetica Lemm.		7	8	10
Marssoniella elegans Lemm.				
Merismopedia glauca (Ehr.) Naegeli				
M. tenuissima Lemm.				
Microcystis aeruginosa Kuetz.	17	61	52	34
Oscillatoria sp. Vaucher				
O. agardhii Gomont	10	11		6
O. angusta Koppe				4
O. hamelii Fremy				
O. limnetica Lemm.				
O. minima Gicklhorn				
Pelogloea bacillifera Lauterborn	26	2	70	42
Rhaphidiopsis curvata Fritsch & Rich				
Chlorophyta:				
Actinastrum hantzschii var. fluviatile Schroeder				
Ankistrodesmus braunii (Naeg.) Brunnthaler				
A. convolutus Corda				
A. falcatus (Corda) Ralfs		32	11	8
A. spiralis (Turner) Lemm.		2		
Characium falcatum Schroeder				
C. limneticum Lemm.				
Chariopsis longissima Lemm.				
Chlorella vulgaris Beyerinck				
Chlorococcum humicola (Naeg.) Rabenhorst				
Closteriopsis longissima var. tropica West & West		2	2	
Closterium sp. Nitzsch				
Coelastrum cambricum Archer				
C. microporum Naegeli in A. Braun				
C. scabrum Reinsch				
C. sphaericum Naegeli				
Cosmarium sp. Corda		2	2	2
Crucigenia quadrata Morren			15	8

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
November 1973

continued	1	2	3	4
C. tetrapedia (Kirch.) West & West				
Elakatothrix gelatinosa Wille	4	13	10	11
Golenkinia radiata (Chod.) Wille				2
Kirchneriella elongata G. M. Smith				
K. subsolitaria G. S. Smith				
Lagerheimia ciliata (Lag.) Chodat				
L. longiseta (Lemm.) Printz				
L. quadriseta (Lemm.) G. M. Smith				
L. subsala Lemm.	2			
Mougeotia sp. (C. A. Agardh) Wittrock				
Nephrocytium agardhianum Naegeli		2		
Oedogonium sp. Link				4
Oocystis gloeocystiformis Borge	10		8	4
O. lacustris Chodat		7	2	2
O. novae-semliae Wille				
O. pusilla Hansgirg	2		6	6
O. submarina Lagerheim				
Pediastrum boryanum (Turp.) Meneghini				
P. duplex var. *clathratum* (A. Braun) Lagerheim				
P. simplex var. *duodenarium* (Bailey) Rabenhorst				
P. tetras (Ehr.) Ralfs				
Phymatodocis sp. Nordstedt				
Planktosphaeria gelatinosa G. M. Smith				
Pleurotaenium sp. Naegeli			2	
Polyblepharides sp. Dangeard.				
Rhizoclonium sp. Kuetz.				
Scenedesmus abundans (Kirch.) Chodat		2	2	2
S. bijuga (Turp.) Lagerheim				
S. denticulatus Lagerheim	2		2	2
S. dimorphus (Turp.) Kuetz.				
S. incrassatulus Bohlin				
S. opoliensis P. Richter	2		2	
S. quadricauda (Turp.) de Brebisson		2	2	2
Schroederia setigera Lemm.			2	
Selenastrum minutum (Naeg.) Collins	4	4	2	2
S. westii G. M. Smith				
Staurastrum sp. Meyen				
Tetradesmus wisconsinense G. M. Smith				
Tetraedron caudatum (Corda) Hansgirg	2			
T. duospinum Ackley				
T. lunula (Reinsch) Wille				
T. minimum (A. Braun) Hansgirg			4	
T. regulare Kuetz.				
T. trigonum var. *gracile* (Reinsch) Detoni				
Tetraspora lacustris Lemm.				
Tetrastrum staurogeniaeforme (Schroeder) Lemm.				
Treubaria triappendiculata Bernard				
Ulothrix sp. Kuetz.				
Chrysophyta:				
Diceras phaseolus Fott	4	2		
Dinobryon sp. Ehr.				

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)

November 1973

continued	1	2	3	4
D. bavaricum Imhof		2	6	
D. calciformis Bach				
D. divergens Imhof	2	6	8	10
D. sertularia Ehr.				
D. tabellariae (Lemm.) Pascher *in* Pascher & Lemm.				
Kephyrion ovum Pascher				
Lagynion ampullaceum (Stokes) Pascher				
Mallomonas acaroides Perty		2	2	
M. caudata Iwanoff				
M. urnaformis Prescott				
Ophiocytium capitatum Wolle				
Synura uvella Ehr.				
Bacillariophyta:				
Achnanthes spp. Bory				
Amphipleura sp. Kuetz.				
Amphora sp. Ehr.		6	2	
Asterionella formosa Hassall	15	19	78	50
Chaetoceras sp. Ehr.				
Cocconeis sp. Ehr.				
Coscinodiscus rothii (Ehr.) Grun.				
Cyclotella spp. Kuetz.	76	24	83	32
C. glomerata Bachmann				
C. catenata Brun.		6	4	17
Cymatopleura elliptica (Breb.) W. Smith				
C. solea (Breb.) W. Smith	2			
Cymbella spp. Agardh				4
Diatoma tenue var. *elongatum* (Lyngb.)				
D. vulgare Bory			2	
Diploneis sp. Ehr.				2
Epithemia zebra (Ehr.) Kuetz.				2
Fragilaria spp. Lyngbye	7	4	21	
F. brevistriata var. *inflata* (Pant) Hust.				
F. capucina Desm.				
F. crotonensis Kitton	207	113	150	212
F. inflata				
F. pinnata Ehr.				
Gomphonema spp. Agardh				
Gyrosigma sp. Hassall			2	
Melosira distans (Ehr.) Kuetz.				
M. granulata (Ehr.) Ralfs				
M. islandica O. Muell.				
M. italica (Ehr.) Kuetz.	30	23	28	35
M. varians C. A. Ag.				
Navicula spp. Bory	6	4	6	8
N. pupula Kuetz.				2
N. scutelloides W. Smith				
N. tripunctata (O. F. Muell) Bory				
Nitzschia spp. Hassall	8	9	15	13
N. acicularis W. Smith	9			
N. dissipata (Kuetz.) Grun.				4
N. frustulum Kuetz.				

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
November 1973

continued

	1	2	3	4
N. linearis W. Smith	6			
N. palea (Kuetz.) W. Smith				
N. sigmoidea (Ehr.) W. Smith	2		2	4
N. tryblionella Hantzsch				
Opephora martyi Heribaud				
Pinnularia sp. Ehr.		2		
Rhizosolenia eriensis H. L. Smith				
Rhoicosphenia curvata (Kuetz.) Grun.				
Rhopalodia gibba (Ehr.) O. Muell.				
Stephanodiscus astraea (Ehr.) Grun.	9	15	24	22
Surirella sp. Turpin				2
S. angustata Kuetz.				
S. ovalis Breb.				
Synedra spp. Ehr.	24	63	30	72
S. actinastroides Lemm.				
S. ulna (Nitz.) Ehr.				
Tabellaria flocculosa (Roth) Kuetz.	11	2	2	17
Pyrrhophyta:				
Certatium hirundinella (O. F. Muell.) Dujardin				
Glenodinium penardiforme (Linde.) Schiller				
G. pulvisculus (Ehr.) Stein				
Gymnodinium fuscum (Ehr.) Stein				
Euglenophyta:				
Colacium arbuscula Stein		2		
Euglena sp. Ehr.				
E. convoluta Korshikov				
Phascus sp. Dujardin				
Lepocinclis glabra Drezepolski				
Trachelomonas sp. Ehr.				
T. robusta Swirenko			2	
T. volvocina Ehr.				
Other Flagellates:				
Chromulina sp. Cienkowski				
Chroomonas sp. Hansgirg		47	24	24
Chrysococcus sp. Klebs				
Cryptomonas sp. Ehr.				
Nephroselmis olivacea Stein				
Rhodomonas lacustris Pascher	13	6	6	7
Unidentified flagellate				
Total Number of Species (S)	33	36	43	42
Mean Total Individuals/ml (N)	601	526	741	715
Richness ($S/\sqrt{N}$)	1.35	1.57	1.58	1.57
Richness ($S-1/\ln N$)	5.00	5.59	6.36	6.24
Shannon-Weaver Diversity ($\bar{d}$)	2.53	2.82	2.90	2.82

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
November 1973

	5	6	7	19	20	*21	22
Cyanophyta:							
Anabaena flos-aquae (Lyngb.) DeBrebisson		2			2		
A. scheremetievi Elenkin							
A. spiroides var. *crassa* Lemm.							
Anabaenopsis elenkinii Miller							
Aphanocapsa elachista West & West							
Aphanothece gelatinosa (Henn.) Lemm.							
A. microspora (Menegh.) Rabenhorst							
Arthrospira gomontiana Setchell							
Chroococcus dispersus (Keissl.) Lemm.							
C. limneticus Lemm.	8	9	2		8	4	
C. turgidus (Kuetz.) Naegeli	11	8					
Coelosphaerium naegelianum Unger	2	4	2	2	8	4	
Cyanarcus hamiformis Pascher							
Dactylococcopsis acicularis Lemm.							
D. fascicularis Lemm.							
D. rhaphidioides Hansgirg			2				
D. smithii Chodat & Chodat							
Lyngbya sp. Agardh							
L. limnetica Lemm.		5	17		8		
Marssoniella elegans Lemm.							
Merismopedia glauca (Ehr.) Naegeli		2					
M. tenuissima Lemm.							
Microcystis aeruginosa Kuetz.	19	26	17	4	9	7	4
Oscillatoria sp. Vaucher							
O. agardhii Gomont		4		4			9
O. angusta Koppe				15			
O. hamelii Fremy							6
O. limnetica Lemm.				10	2	11	9
O. minima Gicklhorn				2			
Pelogloea bacillifera Lauterborn							
Rhaphidiopsis curvata Fritsch & Rich							
Chlorophyta:							
Actinastrum hantzschii var. *fluviatile* Schroeder							
Ankistrodesmus braunii (Naeg.) Brunnthaler				30			
A. convolutus Corda			2				
A. falcatus (Corda) Ralfs	15	4	26	20	10	11	43
A. spiralis (Turner) Lemm.	6		46	9	2	4	35
Characium falcatum Schroeder	2						
C. limneticum Lemm.			6		2		
Chariopsis longissima Lemm.							
Chlorella vulgaris Beyerinck							
Chlorococcum humicola (Naeg.) Rabenhorst							
Closteriopsis longissima var. *tropica* West & West							
Closterium sp. Nitzsch							
Coelastrum cambricum Archer							
C. microporum Naegeli *in* A. Braun			7				2
C. scabrum Reinsch							
C. sphaericum Naegeli							
Cosmarium sp. Corda		4	6			2	6
Crucigenia quadrata Morren		9	2		9		6

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
November 1973

	5	6	7	19	20	*21	22
continued							
C. tetrapedia (Kirch.) West & West	8			2	4		2
Elakatothrix gelatinosa Wille	8	6		2	2		4
Golenkinia radiata (Chod.) Wille					2		
Kirchneriella elongata G. M. Smith							
K. subsolitaria G. S. Smith							
Lagerheimia ciliata (Lag.) Chodat	2						
L. longiseta (Lemm.) Printz					2		
L. quadriseta (Lemm.) G. M. Smith			2	2			8
L. subsala Lemm.							
Mougeotia sp. (C. A. Agardh) Wittrock							
Nephrocytium agardhianum Naegeli							
Oedogonium sp. Link				2			
Oocystis gloeocystiformis Borge	6	4	2	2	4		
O. lacustris Chodat	4		2	2	2		
O. novae-semliae Wille							
O. pusilla Hansgirg							6
O. submarina Lagerheim				4			
Pediastrum boryanum (Turp.) Meneghini		2	2	2			
P. duplex var. clathratum (A. Braun) Lagerheim							
P. simplex var. duodenarium (Bailey) Rabenhorst		2					
P. tetras (Ehr.) Ralfs							
Phymatodocis sp. Nordstedt							
Planktosphaeria gelatinosa G. M. Smith			4	2			
Pleurotaenium sp. Naegeli							
Polyblepharides sp. Dangeard.							
Rhizoclonium sp. Kuetz.							
Scenedesmus abundans (Kirch.) Chodat		10	22	6	4	15	9
S. bijuga (Turp.) Lagerheim		6	13	21	4	4	15
S. denticulatus Lagerheim	2						2
S. dimorphus (Turp.) Kuetz.	2		6				2
S. incrassatulus Bohlin							
S. opoliensis P. Richter				2			
S. quadricauda (Turp.) de Brebisson	2	4	30	7	4	4	28
Schroederia setigera Lemm.		2					
Selenastrum minutum (Naeg.) Collins	6	2	17	35	4	4	6
S. westii G. M. Smith							
Staurastrum sp. Meyen			2				
Tetradesmus wisconsinense G. M. Smith				2			
Tetraedron caudatum (Corda) Hansgirg			8				2
T. duospinum Ackley				4			
T. lunula (Reinsch) Wille							2
T. minimum (A. Braun) Hansgirg				2			
T. regulare Kuetz.							
T. trigonum var. gracile (Reinsch) Detoni							
Tetraspora lacustris Lemm.							
Tetrastrum staurogeniaeforme (Schroeder) Lemm.			2				
Treubaria triappendiculata Bernard							
Ulothrix sp. Kuetz.							
Chrysophyta:							
Diceras phaseolus Fott							
Dinobryon sp. Ehr.							

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
November 1973

continued	5	6	7	19	20	*21	22
D. bavaricum Imhof	15	15	17	8	4	30	30
D. calciformis Bach							
D. divergens Imhof	26			11	9		
D. sertularia Ehr.					6		21
D. tabellariae (Lemm.) Pascher *in* Pascher & Lemm.							
Kephyrion ovum Pascher	6	2	4	2			
Lagynion ampullaceum (Stokes) Pascher							
Mallomonas acaroides Perty							
M. caudata Iwanoff		2					4
M. urnaformis Prescott							
Ophiocytium capitatum Wolle							
Synura uvella Ehr.							
Bacillariophyta:							
Achnanthes spp. Bory	2					1[illegible]	6
Amphipleura sp. Kuetz.							
Amphora sp. Ehr.	8	30	6	11	4	15	2
Asterionella formosa Hassall	52	133	152	85	113	277	170
Chaetoceras sp. Ehr.						4	
Cocconeis sp. Ehr.	2	2	6	7	9		2
Coscinodiscus rothii (Ehr.) Grun.							
Cyclotella spp. Kuetz.	68	96	216	131	95	114	41
C. glomerata Bachmann							
C. catenata Brun.	15		8				
Cymatopleura elliptica (Breb.) W. Smith							
C. solea (Breb.) W. Smith							
Cymbella spp. Agardh	8	8		6			2
Diatoma tenue var. *elongatum* (Lyngb.)				2			
D. vulgare Bory	2	4					
Diploneis sp. Ehr.		4					
Epithemia zebra (Ehr.) Kuetz.		6					
Fragilaria spp. Lyngbye	15	17	6		19		37
F. brevistriata var. *inflata* (Pant) Hust.							
F. capucina Desm.							
F. crotonensis Kitton	135	234	118	81	233	170	131
F. inflata				76			
F. pinnata Ehr.				4			
Gomphonema spp. Agardh		15		2			
Gyrosigma sp. Hassall		2					
Melosira distans (Ehr.) Kuetz.							
M. granulata (Ehr.) Ralfs	6	4	21	52			
M. islandica O. Muell.			9	4			
M. italica (Ehr.) Kuetz.	30	96	28	9	22	22	59
M. varians C. A. Ag.			2				
Navicula spp. Bory	21	24	19	6	7	41	26
N. pupula Kuetz.		2					
N. scutelloides W. Smith							
N. tripunctata (O. F. Muell) Bory							
Nitzschia spp. Hassall	8	17		2	6	18	33
N. acicularis W. Smith			4		2	4	
N. dissipata (Kuetz.) Grun.	2	2	2	2			
N. frustulum Kuetz.	4		22	11	6		

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)

continued

	November 1973						
	5	6	7	19	20	*21	22
N. linearis W. Smith	4	2			8	7	17
N. palea (Kuetz.) W. Smith	19	8	70	186	4	15	28
N. sigmoidea (Ehr.) W. Smith			7				
N. tryblionella Hantzsch			2				
Opephora martyi Heribaud							
Pinnularia sp. Ehr.		2					
Rhizosolenia eriensis H. L. Smith							
Rhoicosphenia curvata (Kuetz.) Grun.	2						
Rhopalodia gibba (Ehr.) O. Muell.							
Stephanodiscus astraea (Ehr.) Grun.	21	22	39	22	17	22	21
Surirella sp. Turpin							
S. angustata Kuetz.							
S. ovalis Breb.							
Synedra spp. Ehr.	26	28	59	32	48	41	39
S. actinastroides Lemm.							
S. ulna (Nitz.) Ehr.							
Tabellaria flocculosa (Roth) Kuetz.	10	24	4	8		7	6
Pyrrhophyta:							
Certatium hirundinella (O. F. Muell.) Dujardin							
Glenodinium penardiforme (Linde.) Schiller		2					
G. pulvisculus (Ehr.) Stein							6
Gymnodinium fuscum (Ehr.) Stein							
Euglenophyta:							
Colacium arbuscula Stein							
Euglena sp. Ehr.							2
E. convoluta Korshikov							
Phascus sp. Dujardin							
Lepocinclis glabra Drezepolski							
Trachelomonas sp. Ehr.		2					
T. robusta Swirenko							
T. volvocina Ehr.					2		
Other Flagellates:							
Chromulina sp. Cienkowski							
Chroomonas sp. Hansgirg	26	4	11	2	41		68
Chrysococcus sp. Klebs							
Cryptomonas sp. Ehr.							
Nephroselmis olivacea Stein							
Rhodomonas lacustris Pascher	46	24	65	6	56	74	93
Unidentified flagellate							
Total Number of Species (S)	43	51	52	52	41	29	45
Mean Total Individuals/ml (N)	682	948	1147	963	803	944	1052
Richness ($S/\sqrt{N}$)	1.65	1.66	1.54	1.68	1.45	0.94	9.39
Richness (S-1/lnN)	6.44	7.29	7.24	7.42	5.98	4.09	6.32
Shannon-Weaver Diversity ($\bar{d}$)	3.12	2.86	3.04	2.97	2.64	2.43	3.08

*indicates single samples rather than replicates

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)

May 1974

	1	2	3	4
Cyanophyta:				
Anabaena flos-aquae (Lyngb.) DeBrebisson				
A. scheremetievi Elenkin				
A. spiroides var. *crassa* Lemm.				
Anabaenopsis elenkinii Miller				
Aphanocapsa elachista West & West				
Aphanothece gelatinosa (Henn.) Lemm.				
A. microspora (Menegh.) Rabenhorst		6	8	
Arthrospira gomontiana Setchell				
Chroococcus dispersus (Keissl.) Lemm.			4	4
C. limneticus Lemm.				
C. turgidus (Kuetz.) Naegeli				
Coelosphaerium naegelianum Unger				
Cyanarcus hamiformis Pascher			2	
Dactylococcopsis acicularis Lemm.				
D. fascicularis Lemm.				
D. rhaphidioides Hansgirg				
D. smithii Chodat & Chodat				
Lyngbya sp. Agardh				
L. limnetica Lemm.				
Marssoniella elegans Lemm.				
Merismopedia glauca (Ehr.) Naegeli				
M. tenuissima Lemm.				
Microcystis aeruginosa Kuetz.				
Oscillatoria sp. Vaucher				
O. agardhii Gomont	8	4	2	15
O. angusta Koppe				
O. hamelii Fremy	35	16	18	4
O. limnetica Lemm.		2		9
O. minima Gicklhorn				
Pelogloea bacillifera Lauterborn				
Rhaphidiopsis curvata Fritsch & Rich				
Chlorophyta:				
Actinastrum hantzschii var. *fluviatile* Schroeder				
Ankistrodesmus braunii (Naeg.) Brunnthaler				
A. convolutus Corda				
A. falcatus (Corda) Ralfs	32	35	37	26
A. spiralis (Turner) Lemm.	2	4	7	2
Characium falcatum Schroeder				
C. limneticum Lemm.				
Chariopsis longissima Lemm.				
Chlorella vulgaris Beyerinck				
Chlorococcum humicola (Naeg.) Rabenhorst				
Closteriopsis longissima var. *tropica* West & West				
Closterium sp. Nitzsch	2			
Coelastrum cambricum Archer				
C. microporum Naegeli *in* A. Braun				
C. scabrum Reinsch				
C. sphaericum Naegeli				
Cosmarium sp. Corda	4	2	2	2
Crucigenia quadrata Morren				

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
May 1974

continued	1	2	3	4
C. tetrapedia (Kirch.) West & West				
Elakatothrix gelatinosa Wille	9	6	2	6
Golenkinia radiata (Chod.) Wille				
Kirchneriella elongata G. M. Smith				
K. subsolitaria G. S. Smith				
Lagerheimia ciliata (Lag.) Chodat				
L. longiseta (Lemm.) Printz				
L. quadriseta (Lemm.) G. M. Smith				
L. subsala Lemm.				
Mougeotia sp. (C. A. Agardh) Wittrock				
Nephrocytium agardhianum Naegeli				
Oedogonium sp. Link				
Oocystis gloeocystiformis Borge				
O. lacustris Chodat				
O. novae-semliae Wille				
O. pusilla Hansgirg		4	2	
O. submarina Lagerheim				
Pediastrum boryanum (Turp.) Meneghini				
P. duplex var. *clathratum* (A. Braun) Lagerheim				
P. simplex var. *duodenarium* (Bailey) Rabenhorst				
P. tetras (Ehr.) Ralfs				
Phymatodocis sp. Nordstedt				
Planktosphaeria gelatinosa G. M. Smith				
Pleurotaenium sp. Naegeli				
Polyblepharides sp. Dangeard.	2			
Rhizoclonium sp. Kuetz.				
Scenedesmus abundans (Kirch.) Chodat	2			
S. bijuga (Turp.) Lagerheim	6	2		2
S. denticulatus Lagerheim				
S. dimorphus (Turp.) Kuetz.				
S. incrassatulus Bohlin				
S. opoliensis P. Richter				
S. quadricauda (Turp.) de Brebisson				
Schroederia setigera Lemm.				
Selenastrum minutum (Naeg.) Collins		2		2
S. westii G. M. Smith				
Staurastrum sp. Meyen				
Tetradesmus wisconsinense G. M. Smith				
Tetraedron caudatum (Corda) Hansgirg				
T. duospinum Ackley				
T. lunula (Reinsch) Wille				
T. minimum (A. Braun) Hansgirg			2	
T. regulare Kuetz.				
T. trigonum var. *gracile* (Reinsch) Detoni				
Tetraspora lacustris Lemm.				
Tetrastrum staurogeniaeforme (Schroeder) Lemm.			2	
Treubaria triappendiculata Bernard				
Ulothrix sp. Keutz.				
Chrysophyta:				
Diceras phaseolus Fott				
Dinobryon sp. Ehr.				

continued

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)

May 1974

	1	2	3	4
D. bavaricum Imhof	4	15		35
D. calciformis Bach				
D. divergens Imhof	78	6		
D. sertularia Ehr.	98	115	139	207
D. tabellariae (Lemm.) Pascher in Pascher & Lemm.	61	50	41	32
Kephyrion ovum Pascher		2		
Lagynion ampullaceum (Stokes) Pascher				
Mallomonas acaroides Perty				2
M. caudata Iwanoff				
M. urnaformis Prescott				
Ophiocytium capitatum Wolle				
Synura uvella Ehr.				
Bacillariophyta:				
Achnanthes spp. Bory	2			6
Amphipleura sp. Kuetz.	2			
Amphora sp. Ehr.				
Asterionella formosa Hassall	104	11	50	54
Chaetoceras sp. Ehr.				
Cocconeis sp. Ehr.				
Coscinodiscus rothii (Ehr.) Grun.				
Cyclotella spp. Kuetz.	30	19	59	47
C. glomerata Bachmann				
C. catenata Brun.	33	4	13	
Cymatopleura elliptica (Breb.) W. Smith				
C. solea (Breb.) W. Smith				2
Cymbella spp. Agardh				4
Diatoma tenue var. elongatum (Lyngb.)		2		26
D. vulgare Bory			2	
Diploneis sp. Ehr.				
Epithemia zebra (Ehr.) Kuetz.				
Fragilaria spp. Lyngbye	2			4
F. brevistriata var. inflata (Pant) Hust.				
F. capucina Desm.	41	79		15
F. crotonensis Kitton	216	245	155	146
F. inflata				
F. pinnata Ehr.				
Gomphonema spp. Agardh				
Gyrosigma sp. Hassall				
Melosira distans (Ehr.) Kuetz.				
M. granulata (Ehr.) Ralfs				
M. islandica O. Muell.	81			
M. italica (Ehr.) Kuetz.		22	24	24
M. varians C. A. Ag.		4	57	
Navicula spp. Bory	8	15	4	
N. pupula Kuetz.				
N. scutelloides W. Smith				
N. tripunctata (O. F. Muell) Bory				
Nitzschia spp. Hassall	7		2	
N. acicularis W. Smith	11	2	13	17
N. dissipata (Kuetz.) Grun.				
N. frustulum Kuetz.				

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
May 1974

continued

	1	2	3	4
N. linearis W. Smith				
N. palea (Kuetz.) W. Smith		4	19	6
N. sigmoidea (Ehr.) W. Smith				
N. tryblionella Hantzsch				
Opephora martyi Heribaud				
Pinnularia sp. Ehr.				
Rhizosolenia eriensis H. L. Smith	163	94	55	150
Rhoicosphenia curvata (Kuetz.) Grun.				2
Rhopalodia gibba (Ehr.) O. Muell.				
Stephanodiscus astraea (Ehr.) Grun.	7		19	4
Surirella sp. Turpin				
S. angustata Kuetz.	2			
S. ovalis Breb.				
Synedra spp. Ehr.	205	93	146	205
S. actinastroides Lemm.		8		
S. ulna (Nitz.) Ehr.				
Tabellaria flocculosa (Roth) Kuetz.	382	284	176	283
Pyrrhophyta:				
Certatium hirundinella (O. F. Muell.) Dujardin				
Glenodinium penardiforme (Linde.) Schiller				
G. pulvisculus (Ehr.) Stein		2	6	4
Gymnodinium fuscum (Ehr.) Stein				
Euglenophyta:				
Colacium arbuscula Stein				
Euglena sp. Ehr.				4
E. convoluta Korshikov			2	
Phascus sp. Dujardin				2
Lepocinclis glabra Drezepolski				
Trachelomonas sp. Ehr.				
T. robusta Swirenko				
T. volvocina Ehr.				
Other Flagellates:				
Chromulina sp. Cienkowski	2			
Chroomonas sp. Hansgirg	37	127	32	15
Chrysococcus sp. Klebs				
Cryptomonas sp. Ehr.				
Nephroselmis olivacea Stein		15		
Rhodomonas lacustris Pascher	22	32	11	21
Unidentified flagellate		15		
Total Number of Species (S)	34	36	33	35
Mean Total Individuals/ml (N)	1700	1348	1113	1385
Richness $(S/\sqrt{N})$	0.82	0.98	0.99	0.94
Richness $(S-1/\ln N)$	4.44	4.86	4.56	4.70
Shannon-Weaver Diversity $(\bar{d})$	2,63	2.61	2,71	2.55

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
May 1974

	*5	6	**7	19	20	21	22
Cyanophyta:							
Anabaena flos-aquae (Lyngb.) DeBrebisson							
A. scheremetievi Elenkin							
A. spiroides var. crassa Lemm.							
Anabaenopsis elenkinii Miller							
Aphanocapsa elachista West & West							
Aphanothece gelatinosa (Henn.) Lemm.							
A. microspora (Menegh.) Rabenhorst				2			
Arthrospira gomontiana Setchell							
Chroococcus dispersus (Keissl.) Lemm.							
C. limneticus Lemm.					2		
C. turgidus (Kuetz.) Naegeli							
Coelosphaerium naegelianum Unger							
Cyanarcus hamiformis Paschef	4						
Dactylococcopsis acicularis Lemm.							
D. fascicularis Lemm.							
D. rhaphidioides Hansgirg							
D. smithii Chodat & Chodat							
Lyngbya sp. Agardh							
L. limnetica Lemm.		2		6	2		
Marssoniella elegans Lemm.							
Merismopedia glauca (Ehr.) Naegeli							
M. tenuissima Lemm.							
Microcystis aeruginosa Kuetz.		2					
Oscillatoria sp. Vaucher							
O. agardhii Gomont		11		6	19	22	19
O. angusta Koppe							
O. hamelii Fremy	18	15		15	13	9	
O. limnetica Lemm.	39	6		4	15	13	9
O. minima Cicklhorn							
Pelogloea bacillifera Lauterborn							
Rhaphidiopsis curvata Fritsch & Rich							
Chlorophyta:							
Actinastrum hantzschii var. fluviatile Schroeder							
Ankistrodesmus braunii (Naeg.) Brunnthaler							
A. convolutus Corda					2		
A. falcatus (Corda) Ralfs	55	22		59	45	61	26
A. spiralis (Turner) Lemm.	18	2		37	24	7	15
Characium falcatum Schroeder							
C. limneticum Lemm.							
Chariopsis longissima Lemm.							
Chlorella vulgaris Beyerinck							
Chlorococcum humicola (Naeg.) Rabenhorst							
Closteriopsis longissima var. tropica West & West							
Closterium sp. Nitzsch	4				4		
Coelastrum cambricum Archer							
C. microporum Naegeli in A. Braun							
C. scabrum Reinsch							
C. sphaericum Naegeli							
Cosmarium sp. Corda				2			
Crucigenia quadrata Morren							

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
May 1974

continued	*5	6	**7	19	20	21	22
C. tetrapedia (Kirch.) West & West							
Elakatothrix gelatinosa Wille							
Colenkinia radiata (Chod.) Wille	4	6		4	6	9	2
Kirchneriella elongata G. M. Smith							
K. subsolitaria G. S. Smith							
Lagerheimia ciliata (Lag.) Chodat							
L. longiseta (Lemm.) Printz							
L. quadriseta (Lemm.) G. M. Smith							
L. subsala Lemm.							
Mougeotia sp. (C. A. Agardh) Wittrock							
Nephrocytium agardhianum Naegeli				2	2	2	
Oedogonium sp. Link							
Oocystis gloeocystiformis Borge		2					
O. lacustris Chodat							
O. novae-semliae Wille							
O. pusilla Hansgirg							
O. submarina Lagerheim	4	2		4	2		
Pediastrum boryanum (Turp.) Meneghini							
P. duplex var. *clathratum* (A. Braun) Lagerheim		2					
P. simplex var. *duodenarium* (Bailey) Rabenhorst							2
P. tetras (Ehr.) Ralfs							
Phymatodocis sp. Nordstedt							
Planktosphaeria gelatinosa G. M. Smith							
Pleurotaenium sp. Naegeli							
Polyblepharides sp. Dangeard.							
Rhizoclonium sp. Kuetz.							
Scenedesmus abundans (Kirch.) Chodat							
S. bijuga (Turp.) Lagerheim					4	2	2
S. denticulatus Lagerheim	11	4		4		8	2
S. dimorphus (Turp.) Kuetz.				2			
S. incrassatulus Bohlin							
S. opoliensis P. Richter					2		
S. quadricauda (Turp.) de Brebisson							
Schroederia setigera Lemm.	4	2		4		4	2
Selenastrum minutum (Naeg.) Collins							2
S. westii G. M. Smith							2
Staurastrum sp. Meyen							
Tetradesmus wisconsinense G. M. Smith							
Tetraedron caudatum (Corda) Hansgirg							
T. duospinum Ackley							
T. lunula (Reinsch) Wille							
T. minimum (A. Braun) Hansgirg							
T. regulare Kuetz.							
T. trigonum var. *gracile* (Reinsch) Detoni							
Tetraspora lacustris Lemm.							
Tetrastrum staurogeniaeforme (Schroeder) Lemm.							
Treubaria triappendiculata Bernard							
Ulothrix sp. Keutz.							
Chrysophyta:							
Diceras phaseolus Fott							
Dinobryon sp. Ehr.							

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
May 1974

continued

	*5	6	**7	19	20	21	22
D. bavaricum Imhof	7	13				2	8
D. calciformis Bach							4
D. divergens Imhof				2			
D. sertularia Ehr.	218	130		10	264	233	207
D. tabellariae (Lemm.) Pascher in Pascher & Lemm.	92	57			41	48	52
Kephyrion ovum Pascher							
Lagynion ampullaceum (Stokes) Pascher							
Mallomonas acaroides Perty							
M. caudata Iwanoff							
M. urnaformis Prescott							
Ophiocytium capitatum Wolle							
Synura uvella Ehr.							
Bacillariophyta:							
Achnanthes spp. Bory	7	31		6	10	13	8
Amphipleura sp. Kuetz.							4
Amphora sp. Ehr.		2		13	9	6	4
Asterionella formosa Hassall	145	50		142	148	98	92
Chaetoceras sp. Ehr.	48			65	31		
Cocconeis sp. Ehr.					6		
Coscinodiscus rothii (Ehr.) Grun.							
Cyclotella spp. Kuetz.	358	32		203	71	26	22
C. glomerata Bachmann				760	181	17	
C. catenata Brun.	22						
Cymatopleura elliptica (Breb.) W. Smith					2		
C. solea (Breb.) W. Smith							
Cymbella spp. Agardh				2	2		
Diatoma tenue var. elongatum (Lyngb.)	55	2		24	6		2
D. vulgare Bory				6	4		
Diploneis sp. Ehr.							2
Epithemia zebra (Ehr.) Kuetz.							
Fragilaria spp. Lyngbye					57		8
F. brevistriata var. inflata (Pant) Hust.							
F. capucina Desm.	273	32		196	170	152	187
F. crotonensis Kitton	343	249		255	362	249	122
F. inflata						13	
F. pinnata Ehr.							
Gomphonema spp. Agardh	4	4		2	6		
Gyrosigma sp. Hassall							
Melosira distans (Ehr.) Kuetz.					67		
M. granulata (Ehr.) Ralfs							
M. islandica O. Muell.				59	74	50	4
M. italica (Ehr.) Kuetz.	59	46		54	30	70	63
M. varians C. A. Ag.	295			316	185	76	30
Navicula spp. Bory	8	8		19	28	6	2
N. pupula Kuetz.				6	2	2	
N. scutelloides W. Smith					6		
N. tripunctata (O. F. Muell) Bory		6			9		
Nitzschia spp. Hassall	7	9		6	11	6	30
N. acicularis W. Smith	59	35		35	41	50	30
N. dissipata (Kuetz.) Grun.	4				2		
N. frustulum Kuetz.							

DETROIT RIVER PHYTOPLANKTON
(mean number of individuals/ml from replicate samples)
May 1974

continued	*5	6	**7	19	20	21	22
N. linearis W. Smith		4		4	32	4	
N. palea (Kuetz.) W. Smith	11	19		15	17	35	9
N. sigmoidea (Ehr.) W. Smith	15	6		8	7	10	4
N. tryblionella Hantzsch							
Opephora martyi Heribaud							
Pinnularia sp. Ehr.							
Rhizosolenia eriensis H. L. Smith	63	92		115	131	100	142
Rhoicosphenia curvata (Kuetz.) Grun.							
Rhopalodia gibba (Ehr.) O. Muell.		2			2		
Stephanodiscus astraea (Ehr.) Grun.	11	6		56	26	15	23
Surirella sp. Turpin							
S. angustata Kuetz.							2
S. ovalis Breb.				4			
Synedra spp. Ehr.	391	223		304	369	386	349
S. actinastroides Lemm.							
S. ulna (Nitz.) Ehr.							
Tabellaria flocculosa (Roth) Kuetz.	409	266		351	447	354	408
Pyrrhophyta:							
Certatium hirundinella (O. F. Muell.) Dujardin							
Glenodinium penardiforme (Linde.) Schiller							
G. pulvisculus (Ehr.) Stein							
Gymnodinium fuscum (Ehr.) Stein	4						
Euglenophyta:							
Colacium arbuscula Stein							
Euglena sp. Ehr.	4			7	13		
E. convoluta Korshikov							
Phascus sp. Dujardin							
Lepocinclis glabra Drezepolski				2			
Trachelomonas sp. Ehr.							
T. robusta Swirenko							
T. volvocina Ehr.							
Other Flagellates:							
Chromulina sp. Cienkowski							
Chroomonas sp. Hansgirg	52	6		4	11	8	
Chrysococcus sp. Klebs							
Cryptomonas sp. Ehr.							
Nephroseimis olivacea Stein							
Rhodomonas lacustris Pascher	7	8		6	10	6	
Unidentified flagellate							
Total Number of Species (S)	38	39		47	53	38	37
Mean Total Individuals/ml (N)	3132	1416		3208	3032	2174	1899
Richness ($S/\sqrt{N}$)	0.68	1.04		0.83	0.96	0.81	0.85
Richness ($S-1/\ln N$)	4.60	5.24		5.70	5.49	4.81	4.77
Shannon-Weaver Diversity ($\bar{d}$)	2.76	2.64		2.68	2.97	2.72	2.54

*indicates single samples rather than replicates

**no samples from this station

APPENDIX D-1
Modeling Theory

A general methodogy for modeling biological production in aquatic systems has been described in an earlier report by Canale (1970). This work emphasized the transient behavior of relatively complex ecosystems in single homogeneous zones. The ultimate goal of the project was to suggest how the annual cylce of phytoplankton and nutrient behavior might be simulated mathematically. The report described the complex kinetics of the system as characterized by nonlinear reaction terms and time-variable rate coefficients.

A relatively simpler class of problems is also of interest. These problems are concerned with the steady state distribution of species whose decay or production tendency can be decribed by first order kinetic formulations. The following list of water quality variables has been traditionally analyzed using such assumptions:

1) Total dissolved solids or conductivity
2) Chlorides
3) Any Conservative Chemical Species
4) Total Coliform Bacteria
5) Dissolved Oxygen
6) Biological Oxygen Demand
7) Radioactive Isotopes
8) Nitrogen (Nitrification Process)

This report describes a general user-oriented program capable of calculating the three-dimensional steady state distribution of the above water quality variables in aquatic systems.

Mathematical models which can be useful for informed management of water resources must be based on the diverse chemical, physical, and biological mechanisms active in the system. These mechanisms are recognized by appropriate terms in equations of continuity for each chemical or biological element of interest. Essentially, two distinct types of mechanisms are recognized. First, are those processes which alter the concentration of material within a closed system due to departures of the state from a chemical equilibrium state. The study of the rate of changes toward or away from this equilibrium state is called kinetics. The kinetic expressions may be dependent on species concentration, temperature, light intensity, and pH.

A second process which can bring about changes in the concentration of species results from the mechanical action of the fluid circulation and the subsequent dilution of concentration gradients. The bulk behavior of the circulation is characterized by gross convective transfer, while the random small-scale fluid movement is accounted for by dispersion coefficients and transfer due to concentration gradients alone. The above ideas are summarized by Equation 1′which is a descriptive statement of the continuity law for any material. Equation 2′expresses this same law in mathematical form for a general three-dimensional system.

A direct solution of Equation 2′for natural systems is not possible. Therefore in practice it is necessary to use approximations which are equivalent to considering a continuous body of water as a series of finite interconnected segments as shown in Figure 1′. In this case, the steady-state continuity equation with first order kinetics reduces to the following:

$$V_k \frac{dC_k}{dt} = 0 = \sum_j \{ -Q_{kj}(\alpha_{kj}C_k + \beta_{kj}C_j) + E_{kj}(C_j - C_k) \} - V_k K_k C_k + W_k \qquad (3')$$

where:

C_k = concentration of water quality variable in segment k, (mg/l)

V_k = volume of segment k, (cft)

Q_{kj} = net flow from segment k to segment j (positive ward) (cubic feet per second)

α_{kj} = finite difference weight given by ratio of flow to dispersion, $0<\alpha<1$, dimensionless

β_{kj} = $1-\alpha_{kj}$

E_{kj} = dispersion mixing coefficient between segments k and j (cft/day) = $E_{kj}A_{kj}/\bar{L}_{kj}$

K_k = first order reaction coefficient in segment k for water quality variable C (day -1)

E_{kj} = dispersion coefficient between segments k and j (square miles/day)

A_{kj} = cross-sectional area between segments k and j (square feet)

$\bar{L}_{kj}$ = average of characteristic lengths of segment k and j (feet)

W_k = source (or sink) of variable C in segment k (pounds/day)

C_j = concentration of water quality variable in adjacent segments (mg/l)

The above units for the parameters are those commonly used in practice and may be changed according to user preference.

If all terms involving the variable C are grouped on the left hand sides, Equation 4 is obtained:

$$a_{kk}C_k+\sum_j a_{kj}C_j = W_k \qquad (4')$$

Where:

$$a_{kk} = \sum_j (Q_{kj}\alpha kj+E'_{kj})+V_k K_k$$

$$a_{kj} = Q_{kj}\beta_{kj}-E'_{kj}$$

If n segments are used, then a series of n equations can b written for the n unknowns, C_1, C_2, C_3 ---C_n.

Boundary conditions apply at the interface of the n segments and outer sections of the waterbody. The flow between the boundary and the section is designated Q_{kk}. When Q_{kk} is positive (leaving the section)

$$a_{kk} = \sum_j (Q_{kj}\alpha_{kj} + E'_{kj}) + V_k K_k + Q_{kk}\;{}_{kk} + E'_{kk} \qquad (5')$$

and

$$W_k = W_k + (E'_{kk} - Q_{kk}\beta_{kk})C_B \qquad (6')$$

where C_B is the boundary concentration of the variable C and must be known.

If Q_{kk} is negative then,

$$a_{kk} = \sum_j (Q_{kj}\alpha_{kj} + E'_{kj}) + V_k K_k + Q_{kk}\beta_{kk} + E'_{kk} \qquad (7')$$

and

$$W_k = W_k + (E'_{kk} - Q_{kk}\alpha_{kk})C_B. \qquad (8')$$

The n equations would then be given by:

$$\begin{aligned}
a_{11}C_1 + a_{12}C_2 + \;\ldots\ldots\; + a_{1n}C_n &= W_1 \\
a_{21}C_1 + a_{22}C_2 + \;\ldots\ldots\; + a_{2n}C_n &= W_2 \qquad (9') \\
\cdot \qquad\qquad\qquad\; \ldots\ldots \quad & \;\;\cdot \\
\cdot \qquad\qquad\qquad\; \ldots\ldots \quad & \;\;\cdot \\
\cdot \qquad\qquad\qquad\; \ldots\ldots \quad & \;\;\cdot \\
a_{n1}C_1 + a_{n2}C_2 + \;\ldots\ldots\; + a_{nn}C_n &= W_n
\end{aligned}$$

where the boundary conditions are incorporated into W_k's.

There are a number of numerical procedures for solving such a set of n simultaneous equations in n unknowns. The SSMP uses an MTS subroutine called SLE1 which uses the Gaussian elimination technique.

Equation 3 is suitable for single dependent variables that are not forced by outputs from other quality systems. Examples of such a type are chloride, coliform, and BOD. Other water quality variables such as dissolved oxygen are coupled to other systems. The utilization of oxygen depends on the distribution of BOD, and therefore it is necessary to first obtain the distribution of BOD and then use these results in a continuity equation for D.O.

Thus, the mass balance equation for D.O. is:

$$V_k \frac{dC_k}{dt} = 0 = \sum_j \{-Q_{kj}(\alpha_{kj}C_k + \beta_{kj}C_j) + E_{kj}'(C_j - C_k) + V_k K_{ak}(C_{sk} - C_k) - V_k K_{dk} L_k \pm W_k \tag{10'}$$

where C_{sk} is the saturation value of D.O., K_{ak} is the reaeration coefficient in segment k, K_{dk} is the deoxygenation coefficient, L is the biochemical oxygen demand and $\pm W$ is now interpreted as sources and sinks of D.O. such as benthal demands and photosynthetic production or respiration. With L_k known from previous calculations, the final solution of Equation 10′ is similar to solution of Equation 3′.

As spatial approximations to derivatives have been used in Equations 3′ and 10′, some error are introduced into the analysis. One of the errors is "psuedo or numerical dispersion." It appears due to the assumption of completely mixed finite volumes. Numerical dispersion is defined by Equation 11′.

$$E_{num_{kj}} = \frac{Q_{kj}}{A_{kj}} \bar{L}_{kj}(\alpha_{kj} - 1/2) \tag{11'}$$

When $\alpha_{kj} = 1/2$, $E_{num_{kj}}$ is zero.

On the other hand, it can be shown that for a positive solution the terms off the main diagonal in the left-hand side of Equation 9 should be non-positive. This condition is satisfied if

$$a_{kj} \geq 1 - E_{kj}A_{kj}/L_{kj}\ Q_{kj} \tag{12'}$$

Writing Equation 12 in another way, it is seen that $\bar{L}_{kj}$ must be chosen such that,

$$\bar{L}_{kj} < \frac{E_{kj}A_{kj}}{Q_{kj}} \cdot \frac{1}{(1-\alpha_{kj})} \tag{13'}$$

APPENDIX D-1

For the case of zero numerical dispersion $\alpha_{kj} = 1/2$ and

$$\bar{L}_{kj} \leq \frac{2E_{kj}A_{kj}}{Q_{kj}} \qquad (14')$$

If α_{kj} is set equal to 1/2 and $\bar{L}_{kj}$ is chosen in such a way as to satisfy Equation 14', then it may be necessary to handle many segments However, if α_{kj} differs very much from 1/2, then numerical dispersion would be high. Further, making $\alpha_{kj} = 1/2$ does not imply the best solution for the case of unequal-sized segments.

In SSMP α_{kj} is first set equal to

$$\alpha_{kj} = \frac{L_j}{L_k + L_j} \qquad (15')$$

In other words, the segment whose center is nearer to the interface would have more weightage in determining the concentration at the interface in Equation 3'. The value of α_{kj} is then checked against Equation 12'. If it is not satisfied, then

$$\alpha_{kj} \text{ is made equal to } 1 - \frac{E_{kj}}{2\,Q_{kj}}$$

Choosing proper spatial grids for approximations to the differential equations is still very much an art. The more numerous the segments in a model, the more accurate the resulting solution. However, in such cases the computer costs may be very high, so a compromise is necessary. Considerations of computer size, nature of problems, degree of accuracy, simplicity of the resulting finite difference equations, and availability of verifying field data all influence the choice. For additional details concerning these questions the reader is referred to Thomann (1971).

APPENDIX D-2
Industrial Outfalls - Detroit River

Industry	Model Segment
U.S. Rubber Co.	5
Anaconda - American Brass	9
Allied Chemical (W-100, W107)	11
Great Lakes Steel (W47-53, 56, 101)	15
Allied Chemical (W113,114)	15
Great Lakes Steel Hot Strip (W43)	19
Great Lakes Steel Rolling Mill (W32-41,70)	19
Wyandotte Chemical - North Works	31
Wyandotte Chemical - South Works	37
Pennwalt Chemicals	37
Firestone Tire and Rubber	37
McLouth Steel (W8-11)	49
Mobil Oil Company	56
Chrysler Corp. (W2, 2a, 3, 6)	60
Monsanto (W4, 5, 139)	60
McLouth Steel (W1)	60

*OUTFALLS DESGINATED W - are according to Michigan Water Resources System

APPENDIX D-3
Flow Rates - Detroit River Model

Year	Flow (cfs)
1963	175,000
1968	180,000
1969	180,000
1971	200,000
1972	200,000
1973	200,000

Note: These are the average flow rates used to obtain the results for the Detroit Model.

APPENDIX D-4
Chloride Loads - Detroit River

	1963	1968	1969	1972	1973
Allied Chemical	45	-	-	-	-
Great Lakes Steel Main Plant	18	-	-	-	-
Detroit Waste Treatment Plant	562	1050*	1100*	1180*	1280*
Rouge River	310	270	245	120	120
Wyandotte-North	1300	1500	1400	30	30
Wyandotte-South	65	560	370	100	60
Pennwalt	510	30	20	230	200
Wayne Co. Treatment Plant	35	50*	60*	90*	95*

All loads as thousands (1000) of #/day

*estimated using increase flow rates and concentration measured in 1963

APPENDIX D-4

Chloride Concentrations (U. S. Public Health Loadings)
Detroit River - 1963

Mile Point	Model Segment Numbers					
20.6	11-13	AMC	8	8	8	
		MPC	8	8	8	
17.4 W	19-21	AMC	19	10	10	
		MPC	13.3	8.1	8.0	
14.6 W	31-33	AMC	29	14	10	
		MPC	26	11	9	
12.0 W	37-39	AMC	48	25	18	
		MPC	40	20	12	
8.7 W	56-59	AMC	50	28	20	
		MPC	38	21	13	
3.9	67-70	AMC	40+	40	22	13
		MPC	37	33	20	14
3.9 (cont.)	71-73	AMC	12	12	35	
		MPC	9	-	-	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-4

Chloride Concentrations (estimated loadings)
Detroit River - 1963

Mile Point	Model Segment Numbers					
20.6	11-13	AMC	8	8	8	
		MPC	8	8	8	
17.4 W	19-21	AMC	19	10	10	
		MPC	16	8	8	
14.6 W	31-33	AMC	29	14	10	
		MPC	29	13	10	
12.0 W	37-39	AMC	48	25	18	
		MPC	47	23	13	
8.7 W	56-59	AMC	50	28	20	
		MPC	44	24	14	
3.9	67-70	AMC	40+	40	22	13
		MPC	44	39	23	16
3.9 (cont.)	71-73	AMC	12	12	35	
		MPC	9	-	-	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-4

Chloride Concentrations
DETROIT RIVER - 1968

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	9	9	9	
		MPC	9	9	9	
17.4 W	19-21	AMC	14	11	10	
		MPC	14	9	9	
14.6 W	31-33	AMC	30	13	10	
		MPC	29	12.4	10	
12.0 W	37-39	AMC	45	18	13	
		MPC	44	22	13	
8.7 W	56-59	AMC	42	22	14	
		MPC	40	23	14	
3.9	67-70	AMC	45+	41	22	14
		MPC	40	35	22	15
3.9 (cont.)	71-73	AMC	10	20	40+	
		MPC	10	-	-	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-4

Chloride Concentrations
DETROIT RIVER - 1969

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	8	8	8	
		MPC	8	8	8	
17.4 W	19-21	AMC	13	8.5	8.5	
		MPC	13	8	8	
14.6 W	31-33	AMC	26	11	10	
		MPC	27	11	9	
12.0 W	37-39	AMC	35	15	12	
		MPC	37	21	12	
8.7 W	56-59	AMC	35	20	12	
		MPC	34	21	13	
3.9	67-70	AMC	40+	34	19	12
		MPC	34	31	20	14
3.9 (cont.)	71-73	AMC	9	16	35+	
		MPC	9	-	-	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-4
Chloride Concentrations
DETROIT RIVER - 1972

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	8	8	8	
		MPC	8	8	8	
17.4 W	15-17	AMC	13	8	8	
		MPC	13	8	8	
14.6 W	31-33	AMC	13	11	9	
		MPC	13	11	9	
12.0 W	37-39	AMC	20	12	10	
		MPC	21	12	11	
8.7 W	56-59	AMC	20	13	11	
		MPC	20	12	11	
3.9	67-70	AMC	25+	22	15	10
		MPC	19	18	13	11
3.9 (cont.)	71-73	AMC	9	17	30+	
		MPC	9	16	26	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-4
Chloride Concentrations
DETROIT RIVER - 1973

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	9	9	9	
		MPC	9	9	9	
17.4 W	15-17	AMC	14	9	9	
		MPC	14	9	9	
14.6 W	31-33	AMC	15	11	10	
		MPC	14	12	10	
12.0 W	37-39	AMC	20	13	10	
		MPC	21	13	12	
8.7 W	56-59	AMC	16	13	12	
		MPC	20	14	12	
3.9	67-70	AMC	25	18	13	12
		MPC	20	18	14	12
3.9 (cont.)	71-73	AMC	10	18	30+	
		MPC	10	17	27	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-5

Phenol Loads
Detroit River

	1963	1968	1969	1972	1973
Allied Chemical	2	74	62	65	50
Great Lakes Steel Main Plant	370	150	130	80	110
Detroit Waste Treatment Plant	1260	1390*	1400*	1600	1750
Rouge River	400	60	70	20	20
Wyandotte-North	34	-	-	-	-
Pennwalt	300	85	22	16	
Wayne Co. Treatment Plant	12	20	20	25	25
Mclouth Steel	20	-	-	-	-
Mobil Oil	350	240	260	3	3

All loads in #/day

*estimated values

APPENDIX D-5
Phenol Concentrations
DETROIT RIVER - 1963

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	2	2	2	
		MPC	2	2	2	
17.4 W	15-17	AMC	11	3	2	
		MPC	10	2	2	
14.6 W	31-33	AMC	8	6	3	
		MPC	8	5	3	
12.0 W	37-39	AMC	16	16	10	
		MPC	17	7	5	
8.7 W	56-59	AMC	30	12	8	
		MPC	25	8	5	
3.9	67-70	AMC	6	5	4	4
		MPC	8	6	4	4
3.9 (cont.)	71-73	AMC	2	1	1	
		MPC	3	3	2	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-5

Phenol Concentrations
DETROIT RIVER - 1968

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	2	2	2	
		MPC	2	2	2	
17.4 W	19-21	AMC	9	5	4	
		MPC	8	2	2	
14.6 W	31-33	AMC	5	3	2	
		MPC	5	3	2	
12.0 W	37-39	AMC	6	5	4	
		MPC	6	4	3	
8.7 W	56-59	AMC	11	5	4	
		MPC	12	4	3	
3.9	67-70	AMC	6	5	3	2
		MPC	6	5	3	3
3.9 (cont.)	71-73	AMC	2	2	2	
		MPC	2	2	2	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-5

Phenol Concentrations
DETROIT RIVER - 1969

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	2	2	2	
		MPC	2	2	2	
17.4 W	19-21	AMC	9	3	3	
		MPC	9	2	2	
14.6 W	31-33	AMC	7	4	2	
		MPC	6	4	2	
12.0 W	37-39	AMC	6	5	4	
		MPC	7	5	4	
8.7 W	56-59	AMC	13	5	4	
		MPC	13	5	4	
3.9	67-70	AMC	8	7	4	3
		MPC	8	7	4	4
3.9 (cont.)	71-73	AMC	2	2	2	
		MPC	3	2	2	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-5

Phenol Concentrations

DETROIT RIVER - 1972

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	1.5	1.5	1.5	
		MPC	1.5	1.5	1.5	
17.4 W	15-17	AMC	7	2	1	
		MPC	8	2	1	
14.6 W	31-33	AMC	5	3	2	
		MPC	5	3	2	
12.0 W	37-39	AMC	6	5	4	
		MPC	6	4	3	
8.7 W	56-59	AMC	8	5	4	
		MPC	7	4	3	
3.9	67-70	AMC	6	4	2	1
		MPC	5	4	3	3
3.9 (cont.)	71-73	AMC	1	1	1	
		MPC	2	2	2	

All values as mg/1

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-5
Phenol Concentrations
DETROIT RIVER - 1973

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	1	1	1	
		MPC	1	1	1	
17.4 W	15-17	AMC	7	1	1	
		MPC	8	1	1	
14.6 W	31-33	AMC	5	3	1	
		MPC	5	3	2	
12.0 W	37-39	AMC	5	4	4	
		MPC	6	4	3	
8.7 W	56-58	AMC	5	4	3	
		MPC	6	4	3	
3.9	67-70	AMC	5	3	2	2
		MPC	4	3	3	2
3.9 (cont.)	71-73	AMC	1	1	1	
		MPC	2	1	1	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-6

Iron Loads
Detroit River

	1968	1969	1972	1973
Great Lakes Steel (Zug Island)	7	8	4	4
Detroit Waste Treatment Plant	67*	75*	180	180
Rouge River	11	7	6	6
Great Lakes Steel Rolling + Hot Strip	220	170	4	4
Wayne County	.35*	.35*	.5	.5
Firestone	.25	.25	.2	.2
McLouth Steel	5	15*	5	5

All loadings in thousands (1000) of #/day

*estimated values

APPENDIX D-6

Total Iron Concentrations
Detroit River - 1968

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	.35	.35	.35	
		MPC	.35	.35	.35	
17.4 W	19-21	AMC	2.0	.40	.40	
		MPC	1.6	.37	.35	
14.6 W	31-33	AMC	.87	.56	.45	
		MPC	.96	.66	.46	
12.0 W	37-39	AMC	1.0	.78	.55	
			.97	.83	.67	
8.7 W	56-58	AMC	1.1	1.0	.80	
		MPC	1.1	.83	.70	
3.9	67-70	AMC	1.2	1.0	.80	.60
		MPC	1.1	1.0	.81	.71
3.9 (cont.)	71-73	AMC	.45	.50	.60	
		MPC	.46	.42	.40	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-6

Total Iron Concentrations
Detroit River - 1969

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	.35	.35	.35	
		MPC	.35	.35	.35	
17.4	19-21	AMC	1.5	.40	.40	
		MPC	1.4	.37	.35	
14.6 W	31-33	AMC	.87	.56	.45	
		MPC	.85	.56	.45	
12.0 W	37-39	AMC	.85	.70	.48	
		MPC	.84	.72	.58	
8.7 W	56-58	AMC	1.4	1.2	.72	
		MPC	1.3	.74	.60	
3.9	67-70	AMC	1.0	.80	.70	.60
		MPC	1.3	1.1	.74	.61
3.9 (cont.)	71-73	AMC	.50	.40	.60	
		MPC	.43	.40	.39	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-6

Total Iron Concentrations
Detroit River - 1972

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	.40	.40	.40	
		MPC	.40	.40	.40	
19.0	15-17	AMC	1.0	.40	.40	
		MPC	1.0	.40	.40	
14.6 W	31-33	AMC	.66	.45	.43	
		MPC	.65	.47	.40	
12.0 W	37-39	AMC	.76	.73	.62	
		MPC	.67	.57	.48	
8.7 W	56-58	AMC	.86	.80	.67	
		MPC	.76	.60	.49	
3.9	67-70	AMC	1.2	1.1	.80	.60
		MPC	.76	.71	.57	.50
3.9 (cont.)	71-73	AMC	.45	.45	.50	
		MPC	.40	.38	.38	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-6

Total Iron Concentrations
Detroit River - 1973

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	.35	.35	.35	
		MPC	.35	.35	.35	
19.0	15-17	AMC	1.0	.25	.25	
		MPC	1.0	.36	.35	
14.6 W	31-33	AMC	.66	.45	.40	
		MPC	.65	.47	.40	
12.0 W	37-39	AMC	.66	.55	.50	
		MPC	.66	.57	.48	
8.7 W	56-58	AMC	.75	.50	.48	
		MPC	.75	.57	.48	
3.9	67-70	AMC	.80	.80	.60	.50
		MPC	.75	.70	.56	.50
3.9 (cont.)	71-73	AMC	.40	.30	.50	
		MPC	.40	.38	.38	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-7
AMMONIA LOADING
DETROIT RIVER

	1972	1973
Great Lakes Steel Main Plant	18	20
Detroit Waste Treatment Plant	51*	59*
Rouge River	1	1
Wyandotte - North	3	3
Pennwalt	0.5	0.5
Wayne County	3*	4*
McLouth Steel	1	1

All loadings in thousand's (1000) of #/day

*estimated values

APPENDIX D-7

Ammonia Nitrogen Concentrations

Detroit River - 1972

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	.04	.04	.04	
		MPC	.04	.04	.04	
19.0	15-17	AMC	.29	.06	.06	
		MPC	.29	.05	.04	
14.6 W	31-33	AMC	.40	.15	.05	
		MPC	.30	.17	.07	
12.0 W	37-39	AMC	.35	.15	.10	
		MPC	.36	.24	.17	
8.7 W	56-58	AMC	.35	.20	.15	
		MPC	.37	.24	.18	
3.9	67-70	AMC	.46	.35	.20	.13
		MPC	.36	.33	.23	.19
3.9 (cont.)	71-73	AMC	.10	.05	.05	
		MPC	.07	.06	.05	

All values as mg/l

AMC - average measured concentration - based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-7

Ammonia Nitrogen Concentrations
Detroit River - 1973

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	.03	.03	.03	
		MPC	.03	.03	.03	
19.0	15-17	AMC	.33	.03	.03	
		MPC	.32	.03	.03	
14.6 W	31-33	AMC	.34	.08	.05	
		MPC	.33	.19	.08	
12.0 W	37-39	AMC	.40	.20	.10	
		MPC	.41	.27	.19	
8.7 W	56-58	AMC	.38	.20	.13	
		MPC	.41	.27	.20	
3.9	67-70	AMC	.40	.40	.15	.04
		MPC	.40	.37	.26	.21
3.9 (cont.)	71-73	AMC	.02	.03	.04	
		MPC	.08	.06	.05	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-8

Total Phosphorous Loadings
Detroit River

	1971	1972	1973
Detroit Waste Treatment Plant	27,000	37,000	48,000
Wayne County	3,000	3,000	3,000

All values as #/day

APPENDIX D-8
Total Phosphorous Concentrations
DETROIT RIVER - 1971

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	.03	.03	.03	
		MPC	.03	.03	.03	
19.0	15-17	AMC	.10	.02	.02	
		MPC	.14	.03	.03	
14.6 W	31-33	AMC	.10	.08	.05	
		MPC	.13	.09	.06	
12.0 W	37-39	AMC	.14	.11	.07	
		MPC	.19	.12	.09	
8.7 W	56-58	AMC	.19	.15	.12	
		MPC	.18	.12	.10	
3.9	67-70	AMC	.22	.20	.15	.09
		MPC	.18	.17	.12	.10
3.9 (cont.)	71-73	AMC	.04	.03	.03	
		MPC	.06	.05	.05	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-8
Total Phosphorous Concentrations
DETROIT RIVER - 1972

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	.04	.04	.04	
		MPC	.04	.04	.04	
19.0	15-17	AMC	.09	.03	.03	
		MPC	.17	.04	.04	
14.6 W	31-33	AMC	.10	.07	.03	
		MPC	.17	.11	.06	
12.0 W	37-39	AMC	.12	.07	.05	
		MPC	.23	.14	.11	
8.7 W	56-58	AMC	.14	.12	.08	
		MPC	.21	.15	.11	
3.9	67-70	AMC	.20+	.20	.12	.08
		MPC	.21	.20	.14	.12
3.9 (cont.)	71-73	AMC	.07	.05	.04	
		MPC	.06	.05	.05	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-8

Total Phosphorous Concentrations
DETROIT RIVER - 1973

Mile Point	Model Segment Numbers					
20.6	9-11	AMC	.05	.05	.05	
		MPC	.05	.05	.05	
19.0	15-17	AMC	.13	.04	.04	
		MPC	.22	.05	.05	
14.6 W	31-33	AMC	.13	.07	.06	
		MPC	.21	.14	.08	
12.0 W	37-39	AMC	.13	.10	.06	
		MPC	.26	.18	.14	
8.7 W	56-58	AMC	.18	.10	.07	
		MPC	.25	.19	.15	
3.9	67-70	AMC	.17+	.16	.11	.07
		MPC	.25	.23	.18	.15
3.9 (cont.)	71-73	AMC	.06	.04	.04	
		MPC	.08	.07	.06	

All values as mg/l

AMC - average measured concentration based on stations located within corresponding model segment

MPC - model predicted concentration

APPENDIX D-9

ASSUMED LOADINGS FOR WATER QUALITY PROJECTIONS

Source	Chloride 1000#/day	Phenol #/day	Ammonia Nitrogen #/day	Phosphorus #/day	Iron #/day
Allied Chemical Semet Solvay Division		37	125		
Great Lakes Steel - Blast Furnace Div.		161	9034*		2250***
Detroit Wastewater Treatment Plant	1460[a]	93	8340[b] 33000[c] 67000[d]	4750	33000[e]
Rouge River**	120	20	1000	400	6000
Great Lakes Steel - Hot Strip Mill					3700***
Great Lakes Steel - Rolling Mill					1300***
Wyandotte Chemical North Works	1300		3486*	875*	
Wyandotte Chemical South Works	550		352		
Pennwalt Chemical	509*	3.8*	65		
Wayne County Waste Treatment Plant**	95	25	4000	3000	500
Firestone Tire and Rubber				33*	50*
McLouth Steel - Trenton Plant		26	834		3050***
Mobil Oil Company		20			
Chrysler Corporation		0.5		16.7*	
Monsanto Company				520	
McLouth Steel - Gibraltar Plant					27

* max. allowable loads, average value not available

** estimated values based on 1972-1973 values

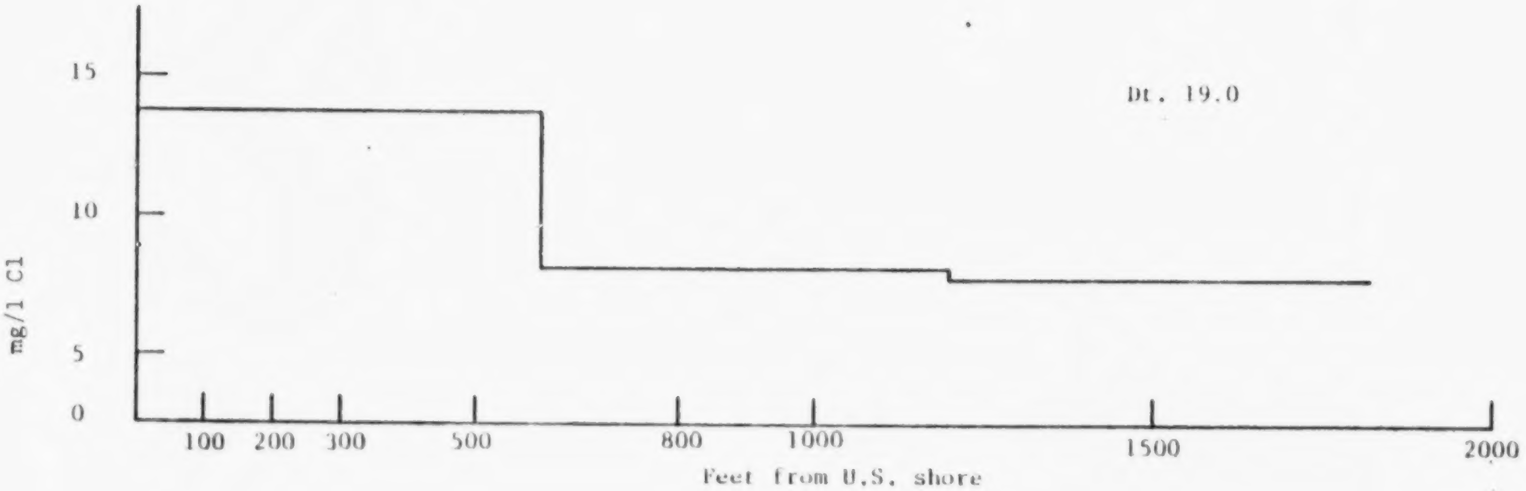
*** permit loading given in mg/l, assumed load based on total plant flow est. and 3 mg/l average

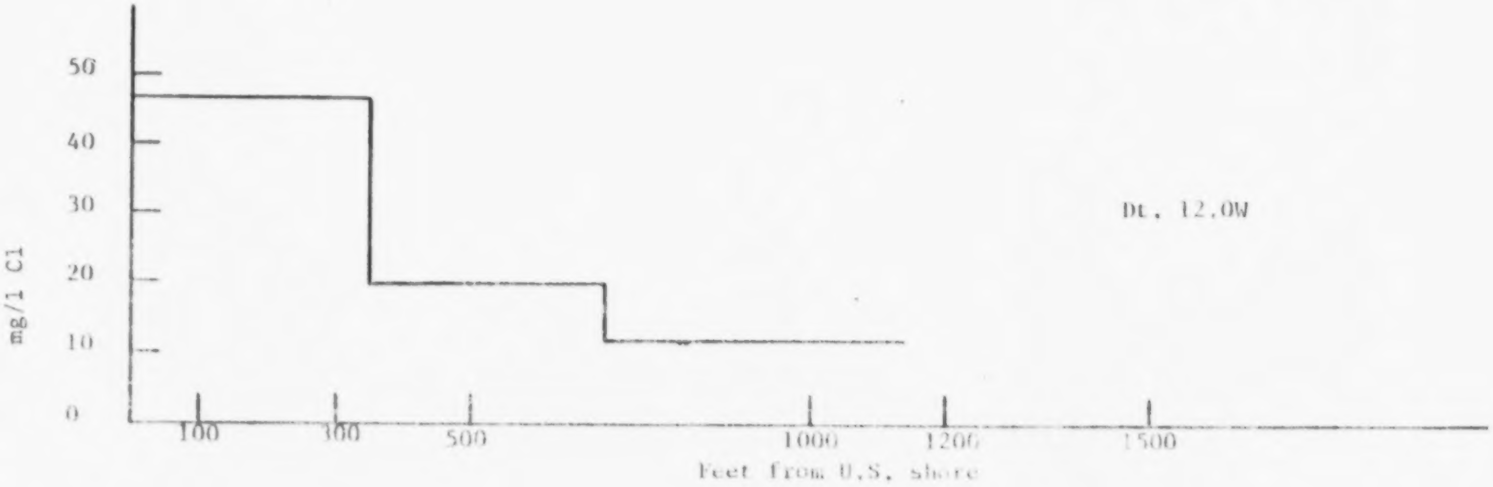
a based on 1 BGD and 175 mg/l ave.

b,c,d based on 1 BGD and 1,4 and 8 mg/l respectively

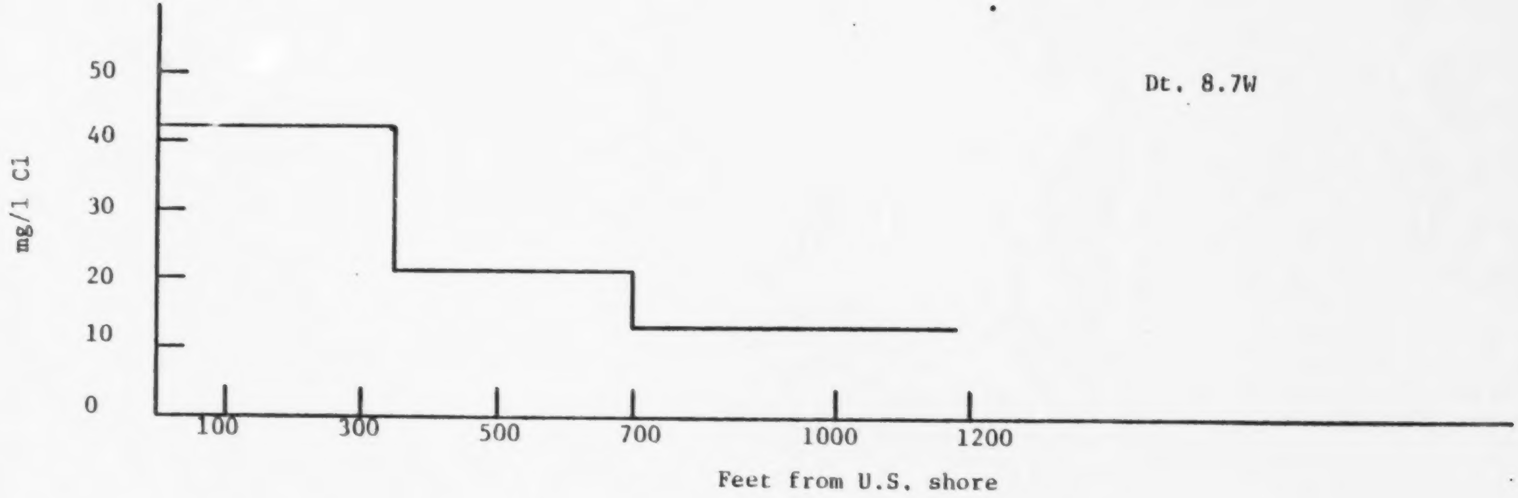
e based on 1 BGD and 4 mg/l average

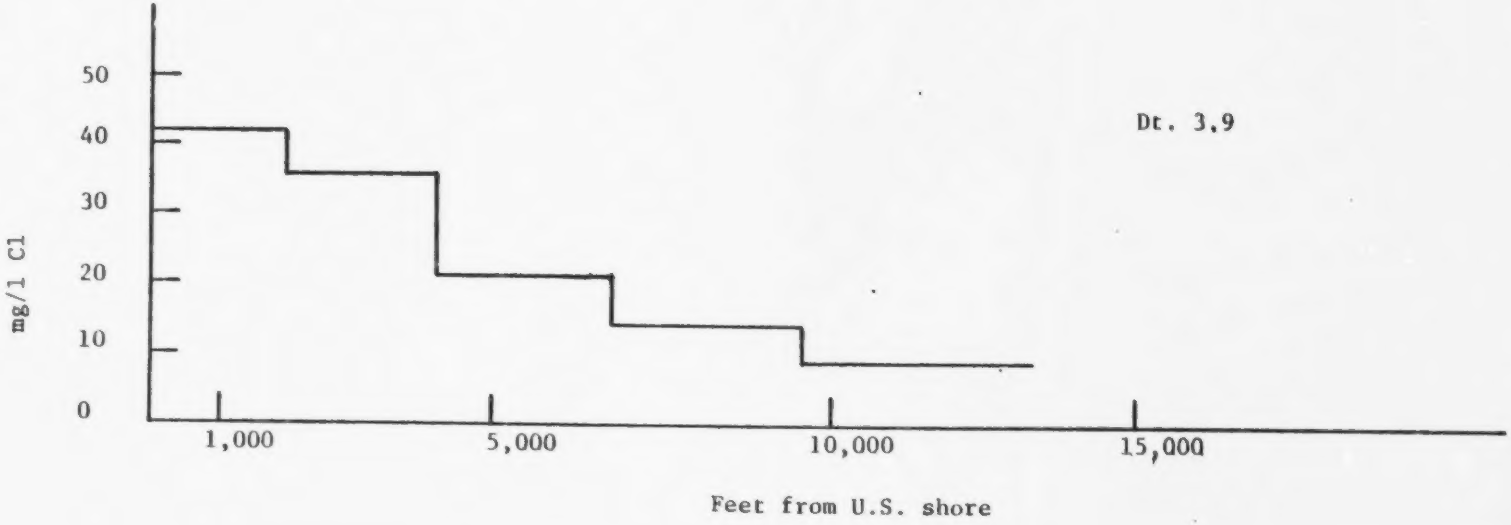
APPENDIX D-9
Water Quality Projections - Chloride
Detroit River - 1977



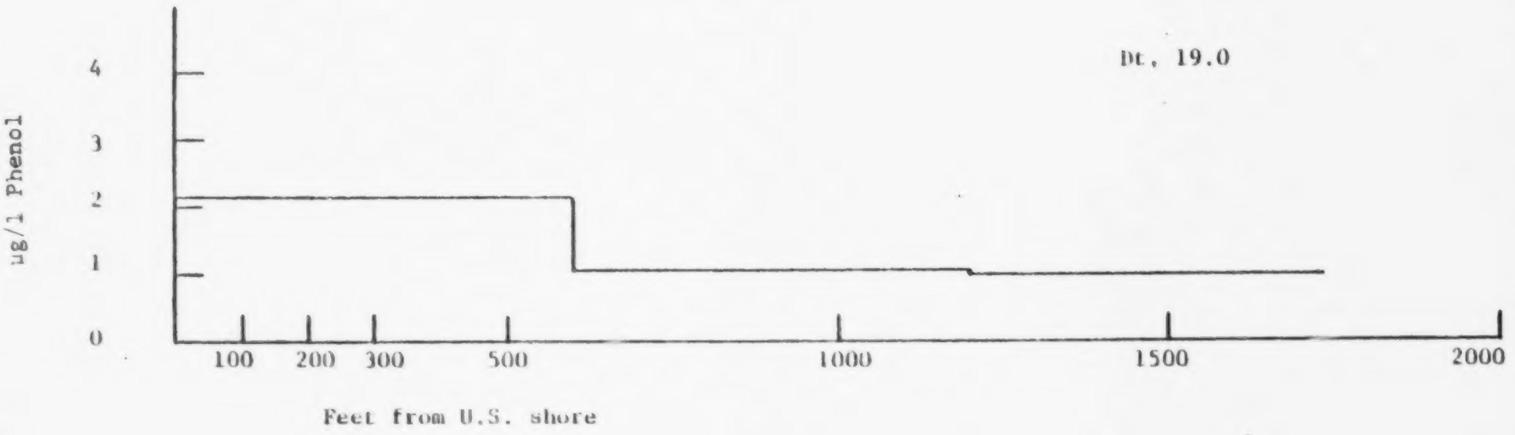


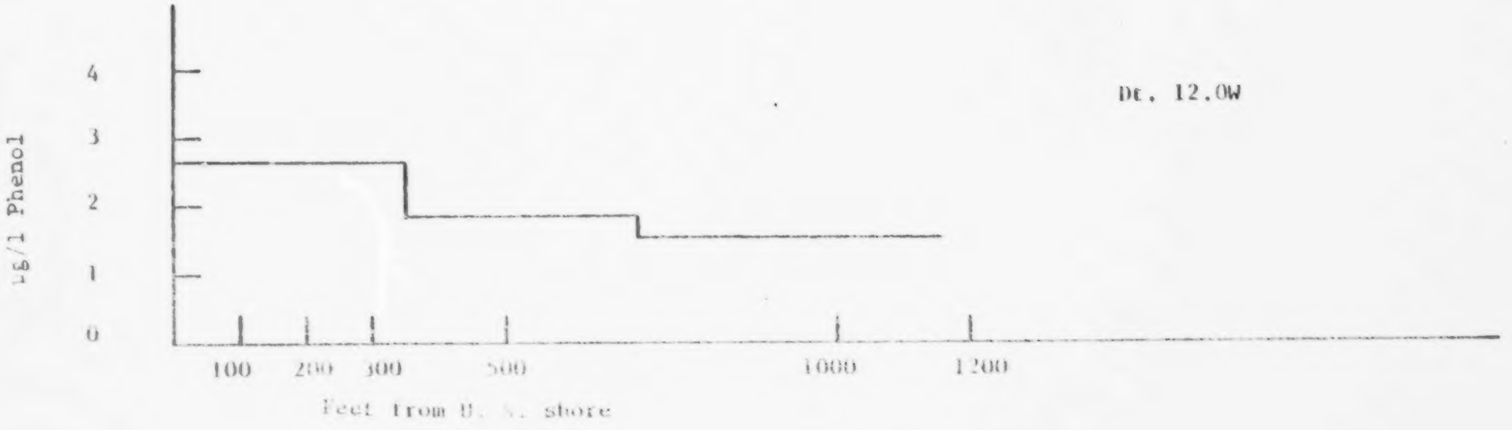
APPENDIX D-9
Water Quality Projections - Chloride
Detroit River - 1977



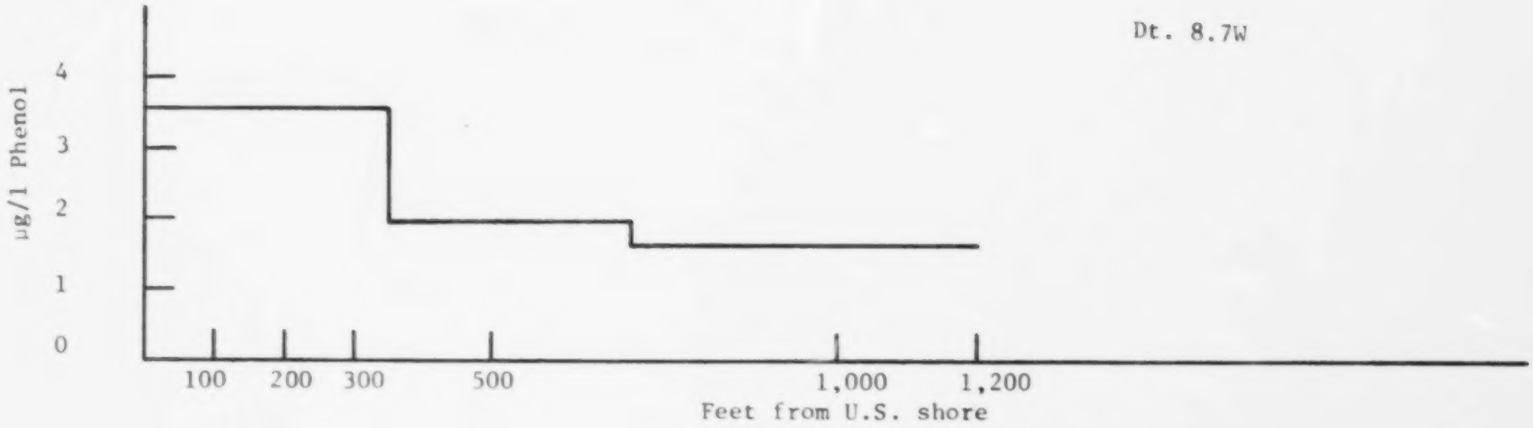


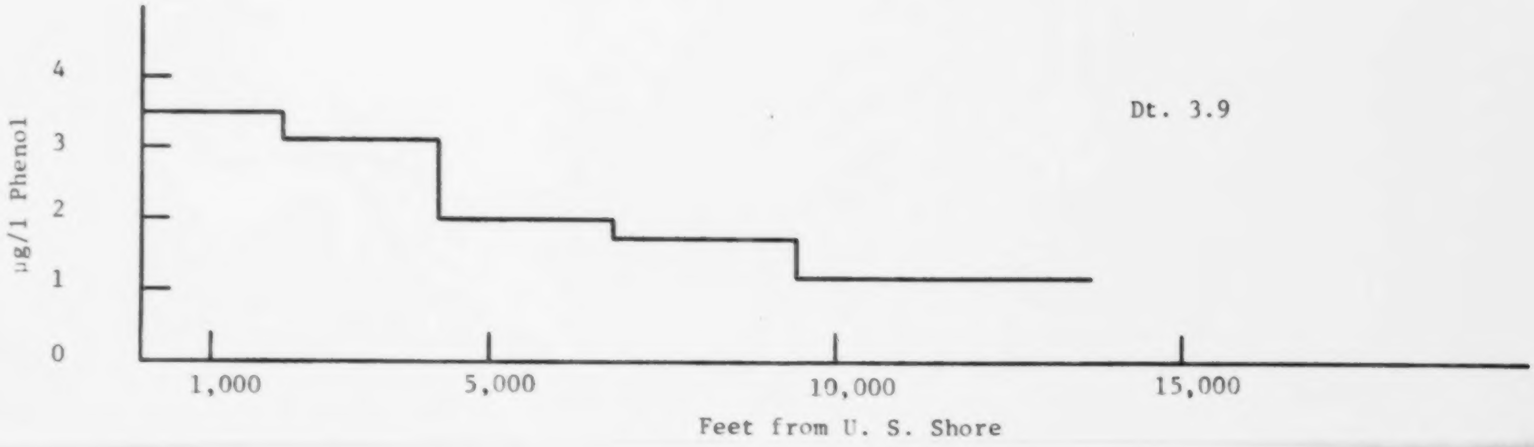
APPENDIX D-9
Water Quality Projections - Phenol
Detroit River - 1977



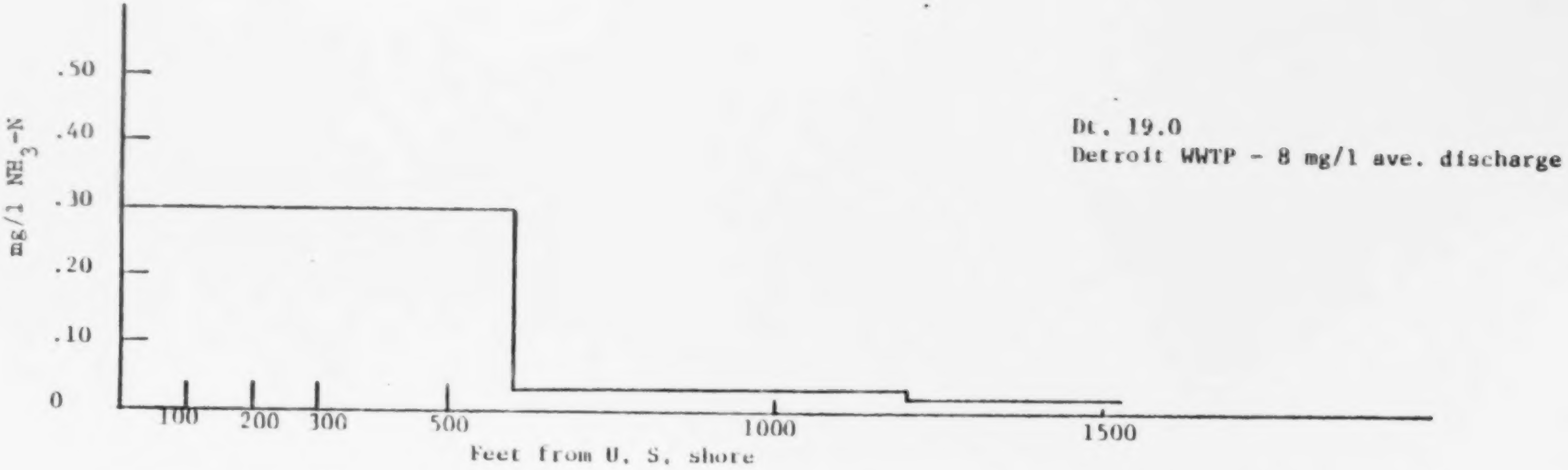


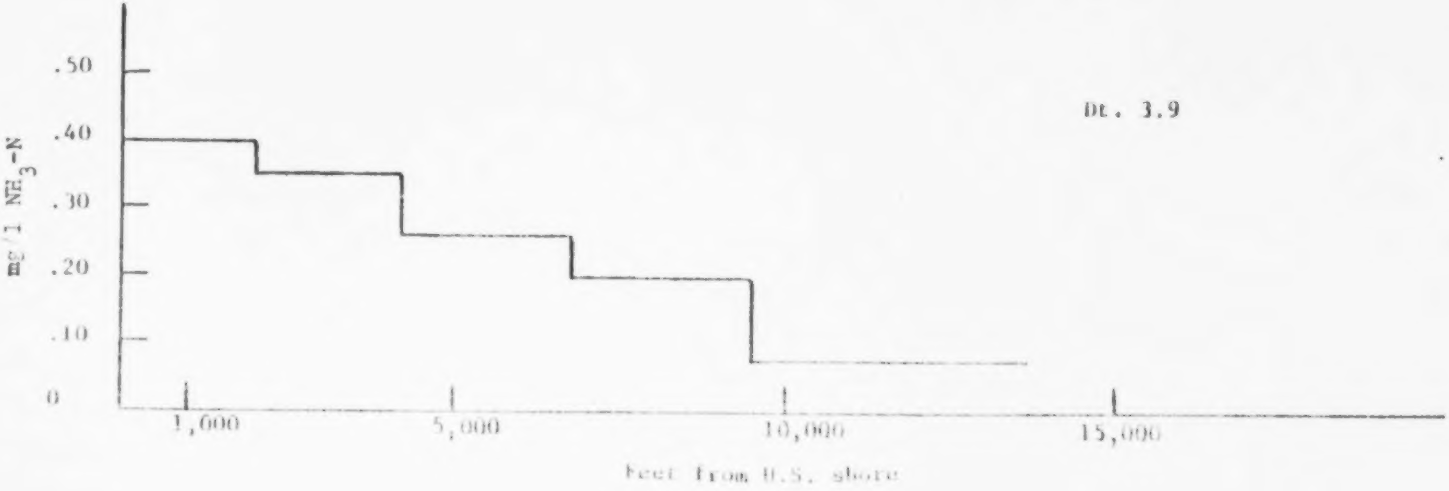
APPENDIX D-9
Water Quality Projections - Phenol
Detroit River - 1977





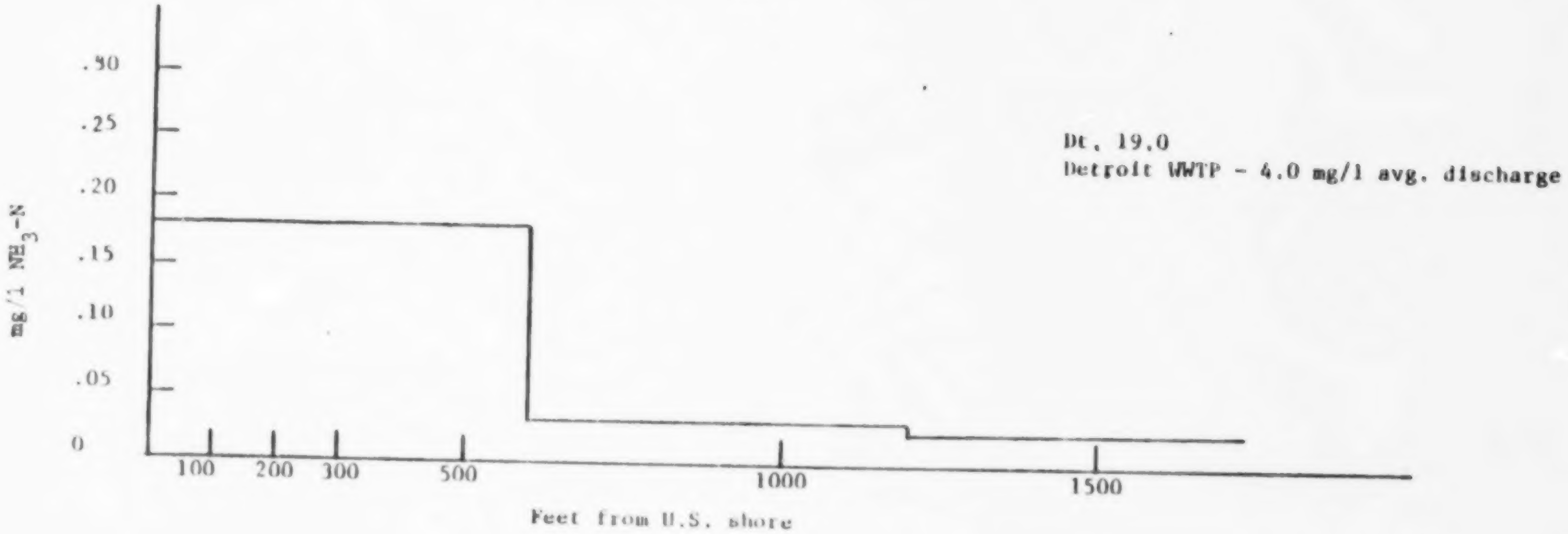
APPENDIX D-9
Water Quality Projection - Ammonia Nitrogen
Detroit River - 1977

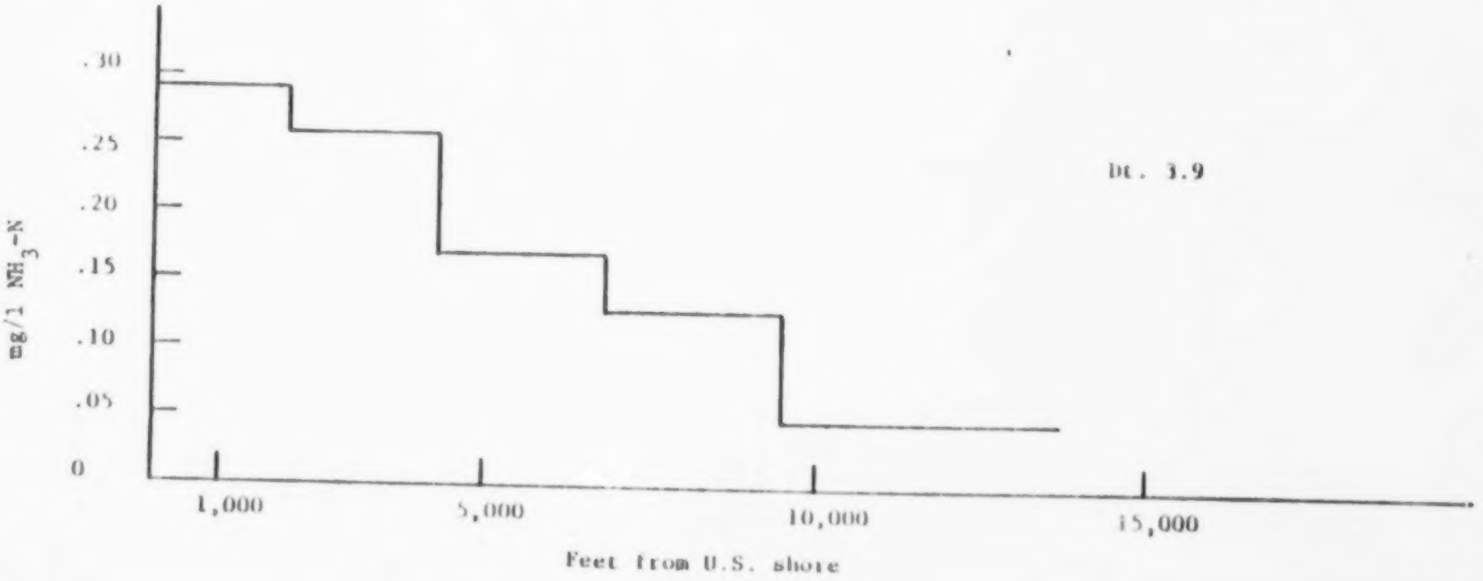




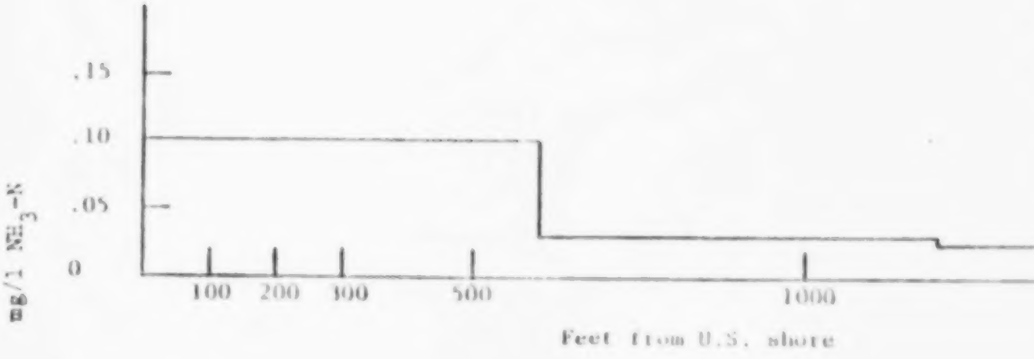
APPENDIX D-9

Water Quality Projection - Ammonia Nitrogen
Detroit River - 1977

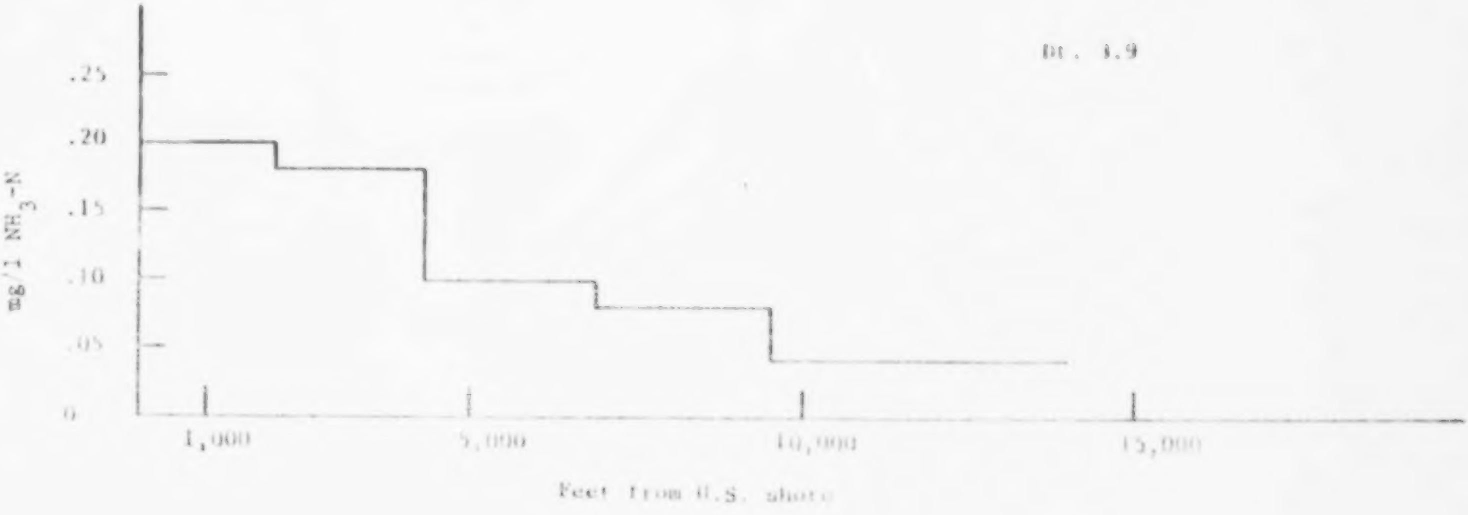




APPENDIX D-9
Water Quality Projection - Ammonia Nitrogen
Detroit River - 1977

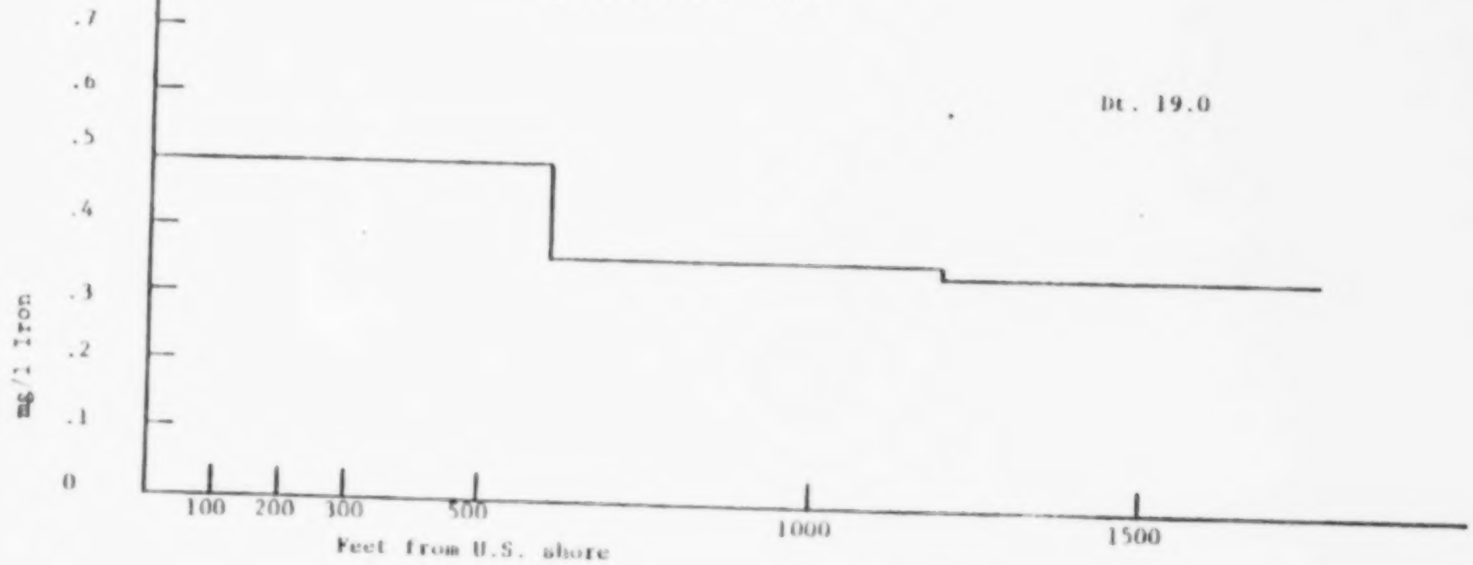


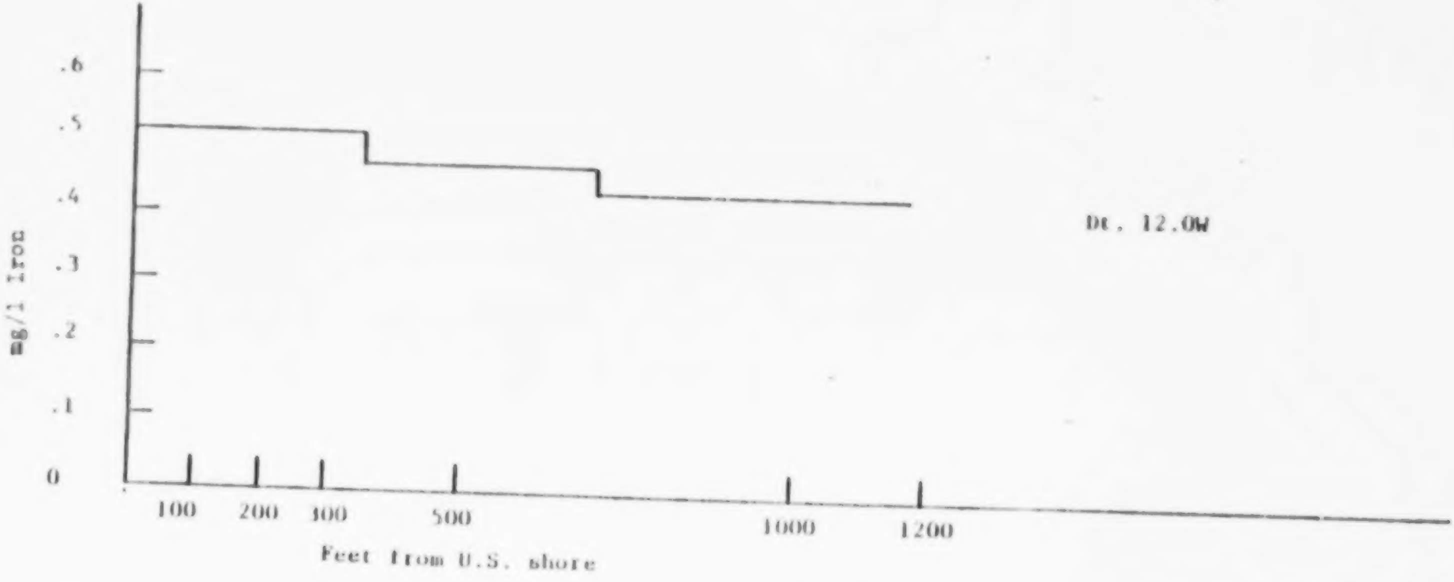
Dt. 19.0
Detroit WWTP - 1.0 mg/l ave. discharge



Dt. 3.9

APPENDIX D-9
Water Quality Projections - Iron
Detroit River - 1977





APPENDIX D-9
Water Quality Projections - Iron
Detroit River - 1977